Titanium Sheet Research Program

North American Aviation, Inc.
Columbus, Ohio

File No.________ Report No. NA57H-527-16

NORTH AMERICAN AVIATION, INC.

COLUMBUS DIVISION COLUMBUS 16, OHIO

ENGINEERING DEPARTMENT

DOD HIGH STRENGTH TITANIUM ALLOY SHEET RESEARCH PROGRAM

31 JANUARY 1962

PREPARED UNDER NAVY BUREAU OF WEAPONS

CONTRACT NOas 57-785d

PROGRESS REPORT #16

PREPARED BY D. E. Myers
D. E. Myers
Producibility Development

APPROVED BY J. R. Macaulay
J. R. Macaulay
Engineering Group Leader
Design Services

K. D. Remington
K. D. Remington
Engineering Manager
Technical Support

No. of Pages 86 REVISIONS Date 31 January 1962

DATE	REV. BY	PAGES AFFECTED	REMARKS

ABSTRACT

This, the first report containing North American Aviation Incorporation's data for the 5-5-5 and 7-12 sheet alloys includes evaluations to be conducted and data obtained to date.

The surface finish and flatness of the sheets were superior to the "heat treatable" alloys evaluated earlier during this program and the sheets tested exceeded target mechanical properties with the exception of the bend radii of one 7-12 sheet. To establish machinability criteria the Box Wilson Statistical Method will be employed. Cleaning requirements for fusion welding are similar to the 5-2½ alloy and preliminary resistance weld tests produced a higher Tension/Shear ratio for the 5-5-5 than the 7-12. Testing, with the exception of creep properties determinations will be completed and reported in the next reporting period of 28 April 1962.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION: North American Aviation, Incorporated, Columbus Division, is evaluating the quality, uniformity, creep properties and fabrication characteristics of the 5Al-5Sn-5Zr. and 7Al-12Zr super alpha titanium sheet alloys under BuWeps Contract NOas57-785d in the Department of Defense Titanium Sheet Rolling Program. Included in these evaluations are tests to determine the possibilities of surface contamination during fabrication and/or contamination effect on fabrication and/or stability of the alloys, particularly the 7Al-12Zr alloy. This the sixteenth progress report presents the first data reported by N.A.A. for the super alpha alloys under Supplemental Agreement #8 to the original contract and covers the period of 1 November 1961 to 31 January 1962.

2. OBJECTIVES: The objectives of these evaluations are to obtain design criteria and to establish methods of fabrication for the materials being tested.

3. SCOPE: The program includes; Receiving Inspection of materials, determination of mechanical properties at room and elevated temperatures, creep properties (welded and un-welded), surface contamination effect on fabrication and/or stability, formability, machinability, dimpling, fusion and resistance welding tests.

4. SUMMARY OF DATA TO DATE

4.1 Receiving Inspection Data: (Reference Paragraph 4.8)

4.1.1 Quantity: A total of twenty eight sheets, BuWeps furnished, are being evaluated, thirteen sheets of the 5-5-5 alloy and fifteen of the 7-12 alloy, under this program.

4.1.2. Deliveries: Deliveries commenced in the middle of August 1961 and were completed in late December 1961.

4.1.3 Surface Condition: The surface condition of all sheets would be acceptable for production parts.

4.1.4 Size: Sixteen sheets (Approx 57%) were under the nominal size of 36 X 96 inches when inspected to AMS 2242 size tolerances.

4.1.5 Gage: Twelve sheets (Approx 43%) failed to meet AMS 2242 thickness tolerances.

4.1.6 Flatness: Excellent flatness was noted for all gages of both alloys.

4.2 Metallurgical Evaluations: Test results obtained by N.A.A. exceeded the target mechanical properties of both alloys with the exception of the minimum bend radii of sheet N.A.A. #69.

4.3 Formability Tests: With the exception of the 6T bend radius for the sheet N.A.A. #69, TMCA supplied .090 gage, heat V1787B, sheet no A7190-2, 7-12 alloy, the minimum bend radii obtained by N.A.A. was within the target bend radii of 4.5T to .070 gage and 5T above .070 gage for the 5-5-5 alloy and 5T for all gages of the 7-12 alloy. Spring-back of 9 -18° for the 5-5-5 and 6 -23° for the 7-12 were noted during the bend tests conducted on these alloys.

4.4 **Machinability Tests:** Milling and Drilling tests are under way using the Box Wilson Statistical Method which requires that all data be available before the cutting tool material, tool geometry, tool life, machine speeds and feeds, coolant, part temperature and finish can be established.

4.5 **Dimpling Tests:** Several tests have been conducted on single and triple action equipment and it appears that the single action equipment is not capable of dimpling the alloys.

4.6 **Fusion Weld Tests:** Preliminary test results indicate that the preparation requirements for the alloys are similar to the 5Al-2½Sn alpha alloy.

4.7 **Resistance Welding:** General conclusions based on limited testing completed to date are: The 5Al-5Sn-5Zr alloy has a higher Tension/Shear Ratio than the 7Al-12Zr alloy, when lap shear strength is the criterion the machine settings are not interchangeable for the two alloys and the alloys do not appear to be susceptible to cracking.

4.8 Sheet Materials Being Evaluated

4.8.1 5Al-5Sn-5Zr Alloy

Gage Nominal	Gage Actual	Size	Heat No	Sheet No. Supplier	Sheet No. NAA	Min. Bend Radius X Thickness (T) Supplier	Min. Bend Radius X Thickness (T) NAA
.020	.017-.020	36 X 96	V1813M	A7152-1	73	L 2.0 T T 2.0	4.0 T 3.0
.020	.017-.021	36 X 96	V1813M	A7152-6	74	L 2.0 T 2.4	3.0 4.0
.020	.020-.022	36 X 90	V1785M	A7659-1	75	L 2.4 T 2.4	4.0 4.0
.040	.038-.039	37 X 94	V1813M	A7129-5	76	L 2.5 T 2.5	3.5 4.0
.040	.035-.039	36 X 91	V1785M	A7558-8	77	L 2.4 T 2.4	4.0 4.0
.040	.037-.039	36 X 96	V1813M	A7129-9	78	L 2.5 T 2.5	- -
.062	.051-.056	37 X 95	V1784M	A7331-2	79	L 2.3 T 3.0	2.5 2.5
.062	.054-.057	36 X 91	V1813B	A7562-4	80	L 2.4 T 2.4	2.0 2.5
.062	.036-.060	35 X 96	V1784M	A7331-1	81	L 2.3 T 2.3	2.0 2.5
.090	.089-.100	37 X 88	V1784B	A7065-4	82	L 3.1 T 2.7	3.5 3.5
.090	.084-.088	36 X 96	V1913	A7840-5	83	L 3.1 T 2.7	3.5 3.5
.125	.114-.123	36 X 96	V1813M	A7127-3	84	L 2.6 T 2.6	- -
.125	.116-.124	36 X 84	V1785B	A7640-2	85	L 2.4 T T 2.4 T	4.0 T 4.0 T

NA57H-527-16

4.8.2 7Al-12Zr Alloy

Supplier	Gage Nominal	Gage Actual	Size	Heat No	Sheet No. Supplier	Sheet No. NAA	Min.Bend Radius X Thickness (T) Supplier	Min.Bend Radius X Thickness (T) NAA
TMCA	.020	.020-.024	36 X 96	V1787M	A7316-3	60	L 3.0 T T 3.8	4.5 T 4.5
TMCA	.020	.020-.022	36 X 95	V1786T	A7320-4	61	L 2.4 T 2.4	3.5 4.0
RMI	.020	.015-.019	34½X70¼	32558	3174-4	62	L 2.4 T 2.4	3.0 3.5
TMCA	.040	.036-.040	36 X 91	V1787M	A7325-5	63	L 2.5 T 2.5	3.5 3.0
TMCA	.040	.037-.039	36 X 96	V1788T	A7556-3	64	L 2.8 T 3.1	- -
RMI	.040	.030-.035	36½X95½	32558	3175-5	65	L 2.4 T 2.4	3.5 4.5
TMCA	.062	.056-.059	36 X 94	V1786M	A7561-3	66	L 3.2 T 3.2	3.5 3.5
RMI	.062	.056-.070	36 X 76	32558	3176-8	67	L 3.0 T 2.0	3.0 3.0
RMI	.062	.060-.073	36 X 75	32885	3176-4	68	L 3.0 T 3.5	3.0 3.5
TMCA	.062	.054-.057	36 X 96	V1786M	A7561-4	86	L 3.6 T 3.2	3.5 3.0
TMCA	.090	.091-.096	36 X 96	V1787B	A7190-2	69	L 3.2 T 3.2	6.0 6.0
TMCA	.090	.082-.091	37 X 96	V1787T	A7326-2	70	L 3.5 T 3.5	3.5 3.5
TMCA	.125	.115-.121	36 X 96	V1788M	A7661-2	71	L 2.4 T 2.2	- -
RMI	.125	.115-.126	36½X89 5/8	32558	3195-5	72	L 2.6 T 2.6	4.0 4.0
TMCA	.125	.112-.117	37 X 99	V1914B	A7662-4	87	L 2.4 T 2.5 T	4.0 4.0 T

5. **FUTURE WORK:** With the exception of determination of creep properties the evaluations programmed for the 5-5-5 and 7-12 alloys will be completed and reported, including data obtained, conclusions and recommendations, in the next reporting period of 28 April 1962. Reference applicable Appendicies for details of evaluations to be conducted under this program.

APPENDIX I

RECEIVING INSPECTION DATA

AND

LAYOUT OF SHEET BEING EVALUATED

ABSTRACT

The total quantity of sheets required for this program have been received, inspected and lay-out of areas of specific evaluations for each sheet is complete.

1. INTRODUCTION: Receiving Inspection of test sheets consists of surface condition (visual), size, gage and flatness. Other standard receiving inspection requirements such as determining mechanical properties have been allocated, in this program, to other areas of investigation and data will appear in the applicable sections of this and future reports.

2. INSPECTION & LAYOUT PRINTS: Reference pages 16 through 43 for data on each sheet as to, alloy, gage, heat number, suppliers sheet number, flatness, surface condition, supplier and N.A.A. identification, N.A.A. inspection data and layout of areas from which specimens for specific evaluations are taken.

3. MATERIALS DATA:

3.1 Quantity Received: The total of twenty eight BuWeps furnished sheets being evaluated under the program have been received. Thirteen sheets of the 5-5-5 and ten sheets of the 7-12 were received from T.M.C.A. The remaining five sheets, of the 7-12, were received from R.M.I.

3.2 Deliveries: The following is a summary of the total range of two to twenty five weeks required from date of BuWeps orders until material was received by N.A.A., Columbus. Reference Figure 1, page 14 for a complete breakdown.

Supplier	Alloy	Quantity	Weeks
T.M.C.A.	5-5-5	13	Eleven to eighteen
T.M.C.A.	7-12	10	Eleven to twenty
R.M.I.	7-12	5	Two to twenty five

3.3 **Surface Condition:** The surface condition of the sheets were free of grind marks, discoloration, pits, inclusions and scratches. All sheets, including the pronounced "orange peel" surfaces of the R.M.I. materials, were classified acceptable for production.

3.4 **Size:** Sixteen sheets (approx 57%) of the total quantity of twenty-eight received were undersize when inspected to AMS 2242 tolerances of plus 1/16, minus "0" for width and plus 1/4, minus "0" for length. The following is a summary of the undersize sheets by alloy and supplier.

	5Al-5Sn-5Zr Supplier - T.M.C.A.		7Al-12Zr Supplier - T.M.C.A.		7Al-12Zr Supplier - R.M.I.	
Total Quantity	13 Sheets		10 Sheets		5 Sheets	
Undersize	Width	Length	Width	Length	Width	Length
Quantity	1	7	0	3	1	5
Percent	8%	54%	0	30%	20%	100%

3.5 **Gage:** Twelve sheets (43%) of the total quantity of twenty eight sheets received were out of AMS 2242 thickness tolerances. Reference Figure 2, page 15 for a plot of sheet thicknesses vs AMS 2242 thickness tolerances. A summary of gage control is as follows:

Supplier	Alloy	Total Quantity	Quantity Out Of Tolerance	Percent Out Of Tolerance
T.M.C.A.	5Al-5Sn-5Zr	13	5	Approx 39%
T.M.C.A.	7Al-12Zr	10	3	30%
R.M.I.	7Al-12Zr	5	4	80%

3.6 **Flatness:** The total quantity of twenty eight sheets received were well within the N.A.A. Columbus flatness requirements for Titanium sheet of 5% for gages through .070 and 3% for gages over .070. The maximum percent of out of flatness for all gages was 1%, based on out of flatness being measured as the percent of the distance between contact points of a straight edge laid in any direction on the sheet.

3.7 **General Comments:** Comparing the super alpha alloys to the 4Al-3Mo-1V, 16V-2½Al and the 3120VCA "heat treatable" alloys, inspected in the early portion of this program, the following were noted.

a) Although, deliveries did not meet promise dates, overall time was less for delivery of the super alpha alloys.

b) With the exception of the pronounced "orange peel" surface of the R.M.I. super alpha materials the surface condition was improved, particularly in respect to the lack of grind marks and discoloration.

c) 57% of the super alpha sheets vs 7% of the "heat treatable" alloys were undersize.

d) Gage control deteriorated for the .040, .062 and .090 gages of the super alpha alloys.

e) The flatness of the super alpha sheets was excellent, a decided improvement over the "heat treatable" alloys.

4. **FUTURE WORK:** The data presented in the Appendix I concludes the receiving inspection of the 5-5-5 and 7-12 alloy sheets required for this program.

FIGURE 1

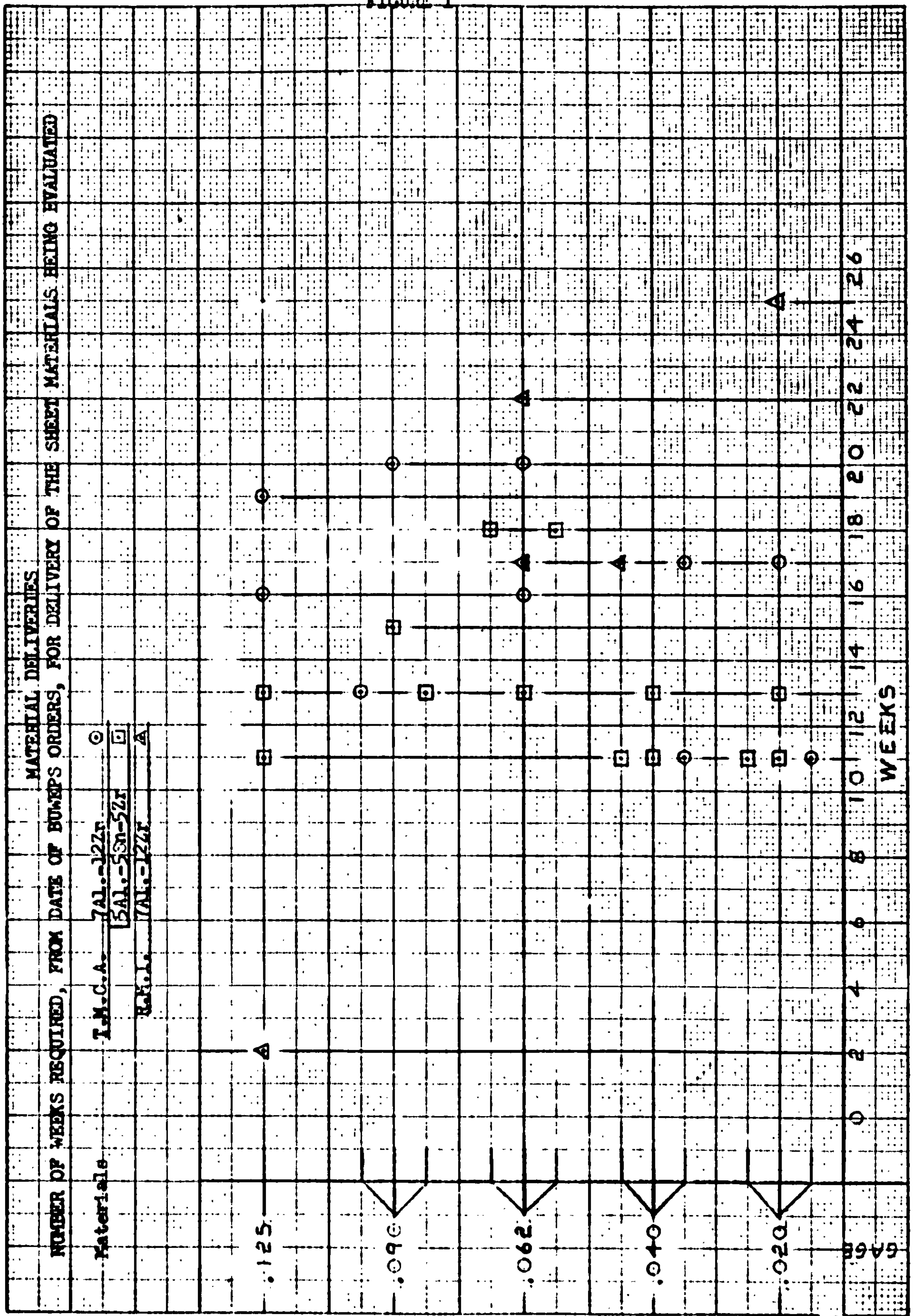
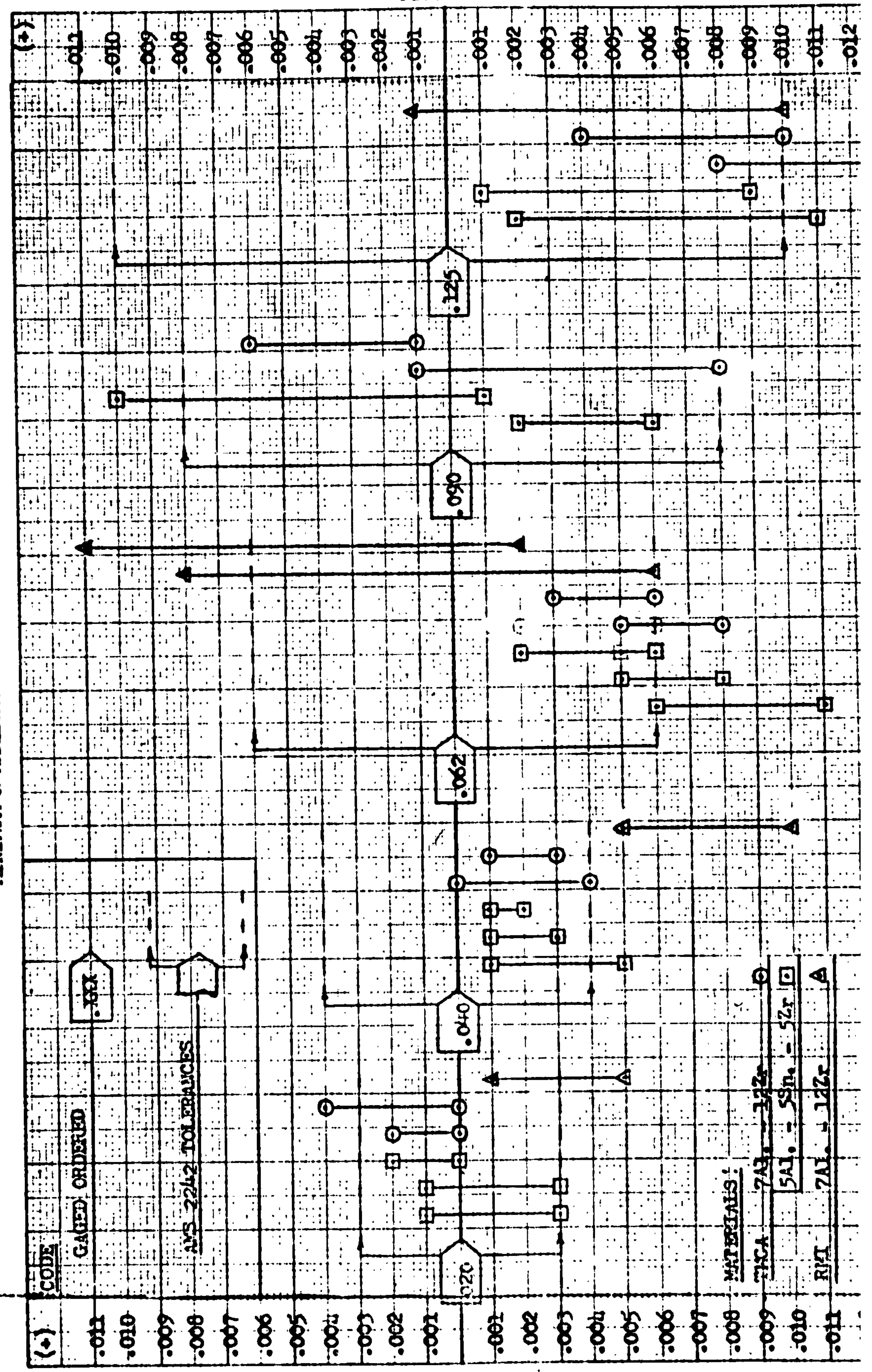

MATERIAL DELIVERIES
NUMBER OF WEEKS REQUIRED, FROM DATE OF BUWEPS ORDERS, FOR DELIVERY OF THE SHEET MATERIALS BEING EVALUATED
Materials
T.M.C.A. 7Al.-12Zr.
5Al.-5Sn-5Zr
R.M.I. 7Al.-12Zr
.125
.090
.062
.040
.020
GAGE
0
2
4
6
8
10
12
14
16
18
20
22
24
26
WEEKS

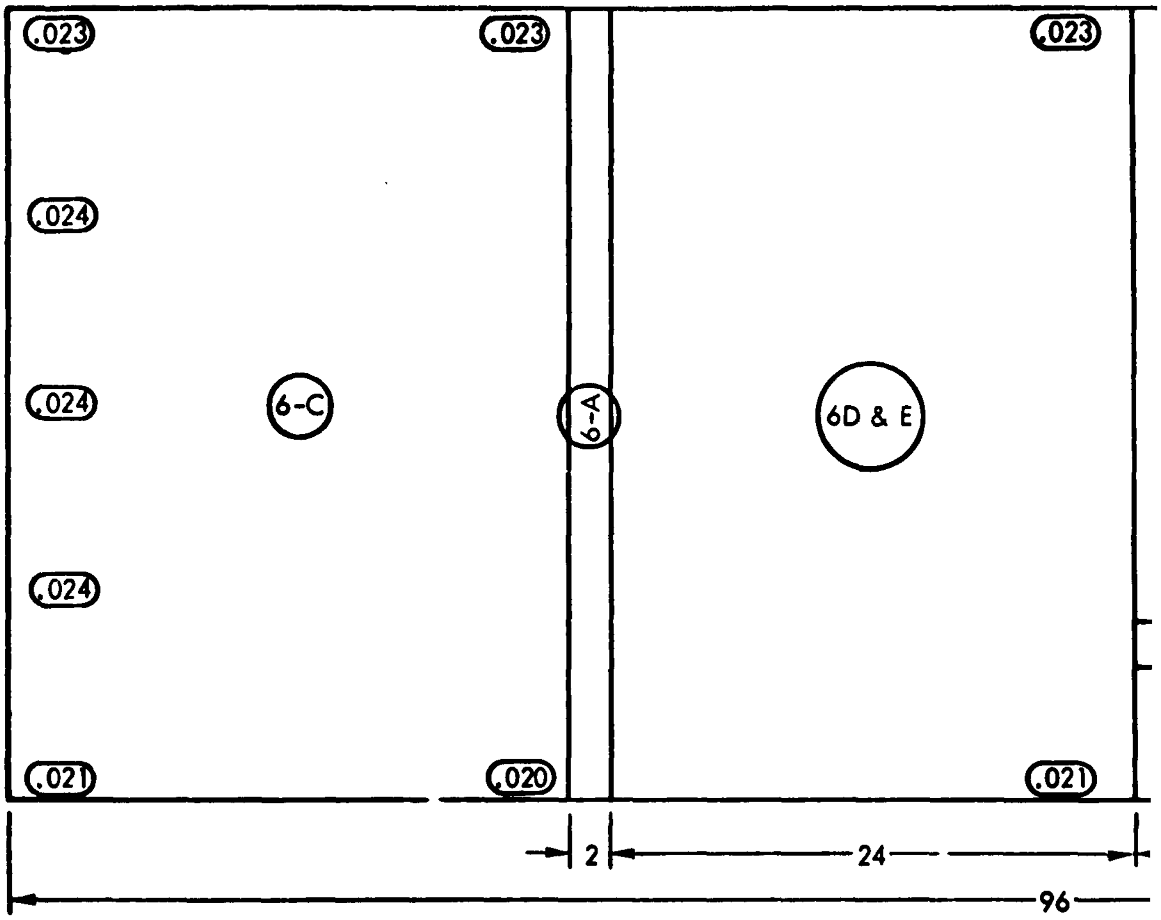
FIGURE 2

MINIMUM & MAXIMUM THICKNESS READINGS PER SHEET



INSPECTION AND LAYOU

1



TEST CODES

① MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

② SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

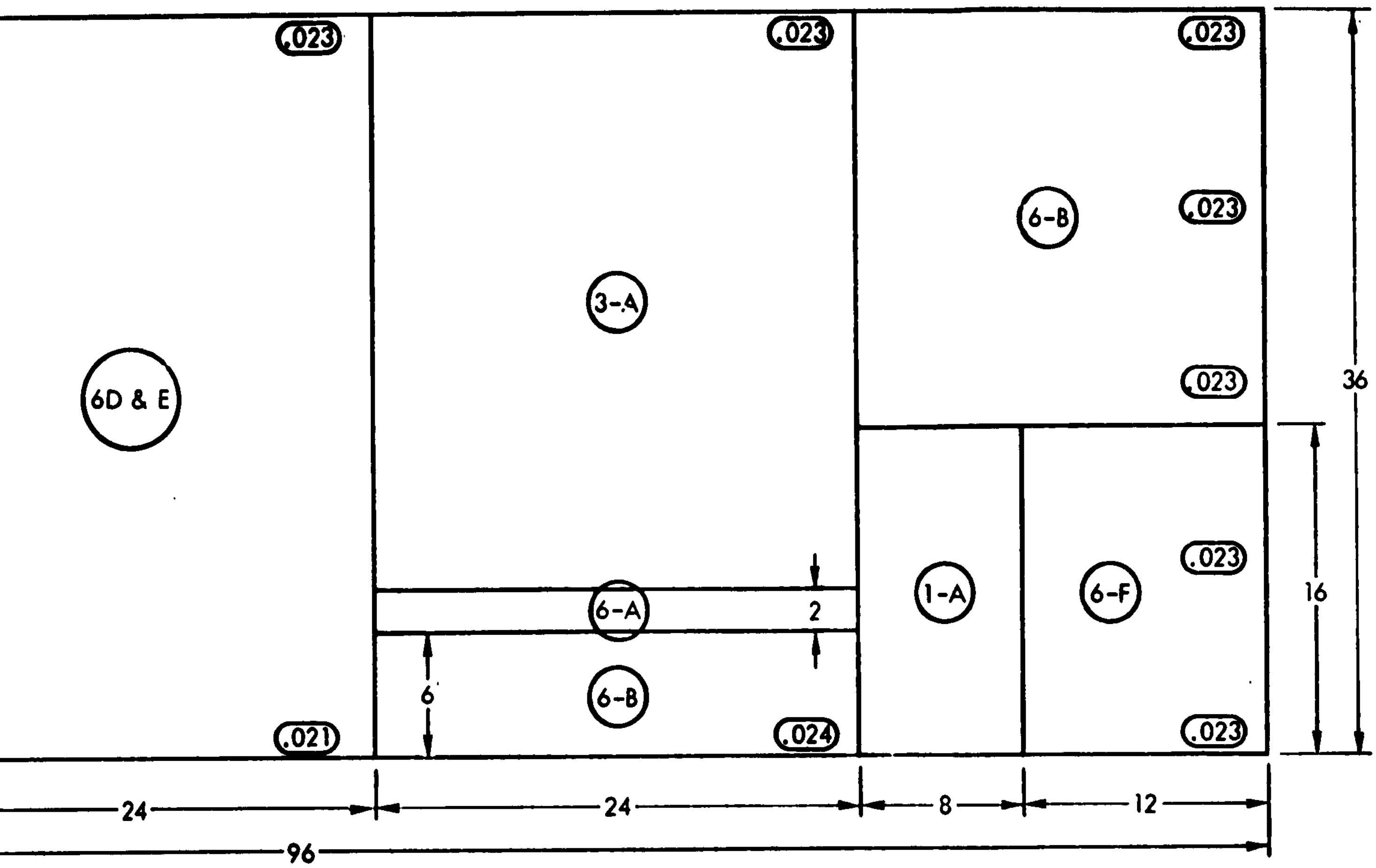
③ RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

④ FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

⑤

⑥

THICKNESS MEASUREMENTS	SURFACE CONDITION: WHITE CORROSIVE LINES A



2

EST CODES

T WELD
OT
M

WELD
LDING PROCEDURE
ECTS OF CHEMISTRY
EP PROPERTIES

5 MACHINABILITY

6 FORMABILITY

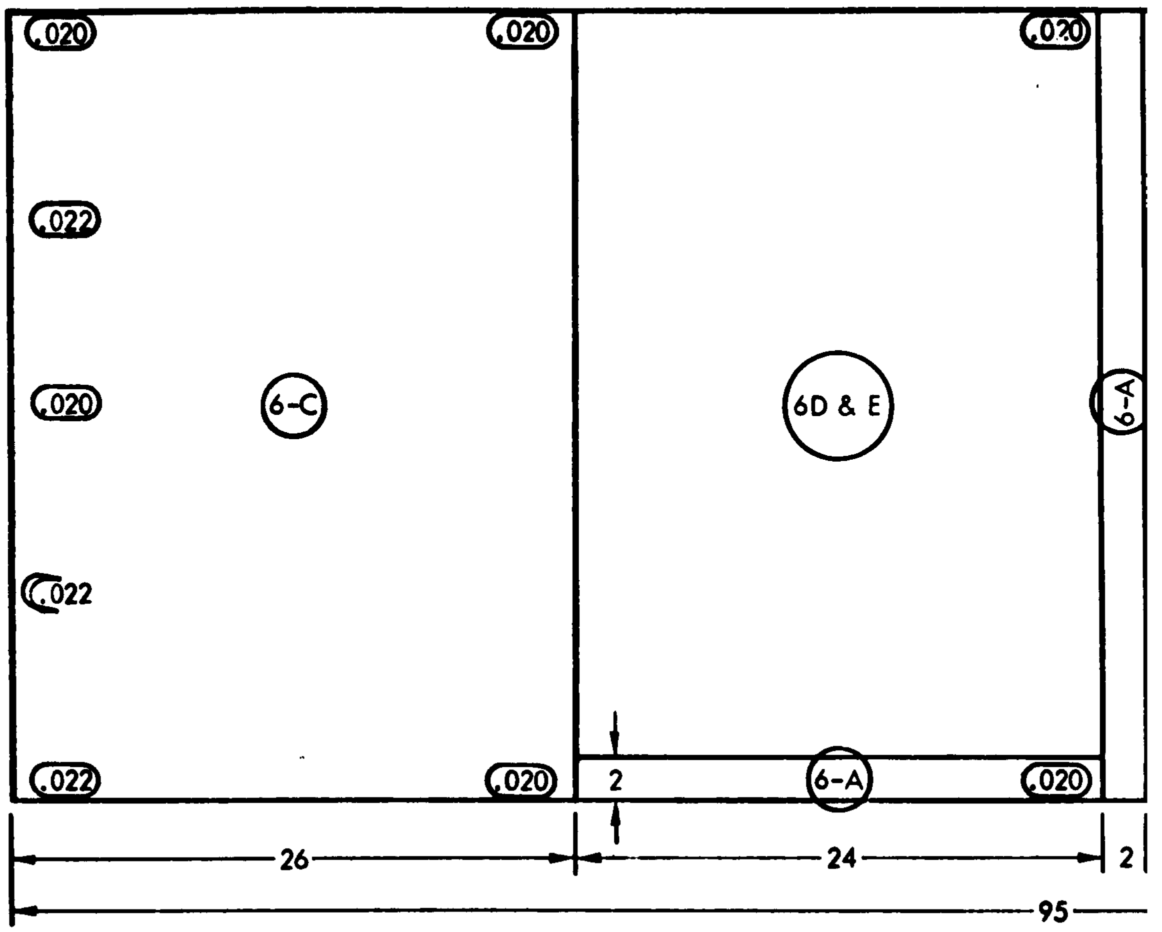
- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

N: WHITE CORROSIVE LINES AND SPOTS BOTH SIDES

MATERIAL DATA	
ALLOY	7A1.-12Zr.
NOMINAL GAGE	.020
ACTUAL GAGE	.020-.024
ACTUAL SIZE	36 X 96
HEAT NO.	V1787M
SHEET NO.	3
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYO

1



TEST CODES

1 MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

2 SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

3 RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

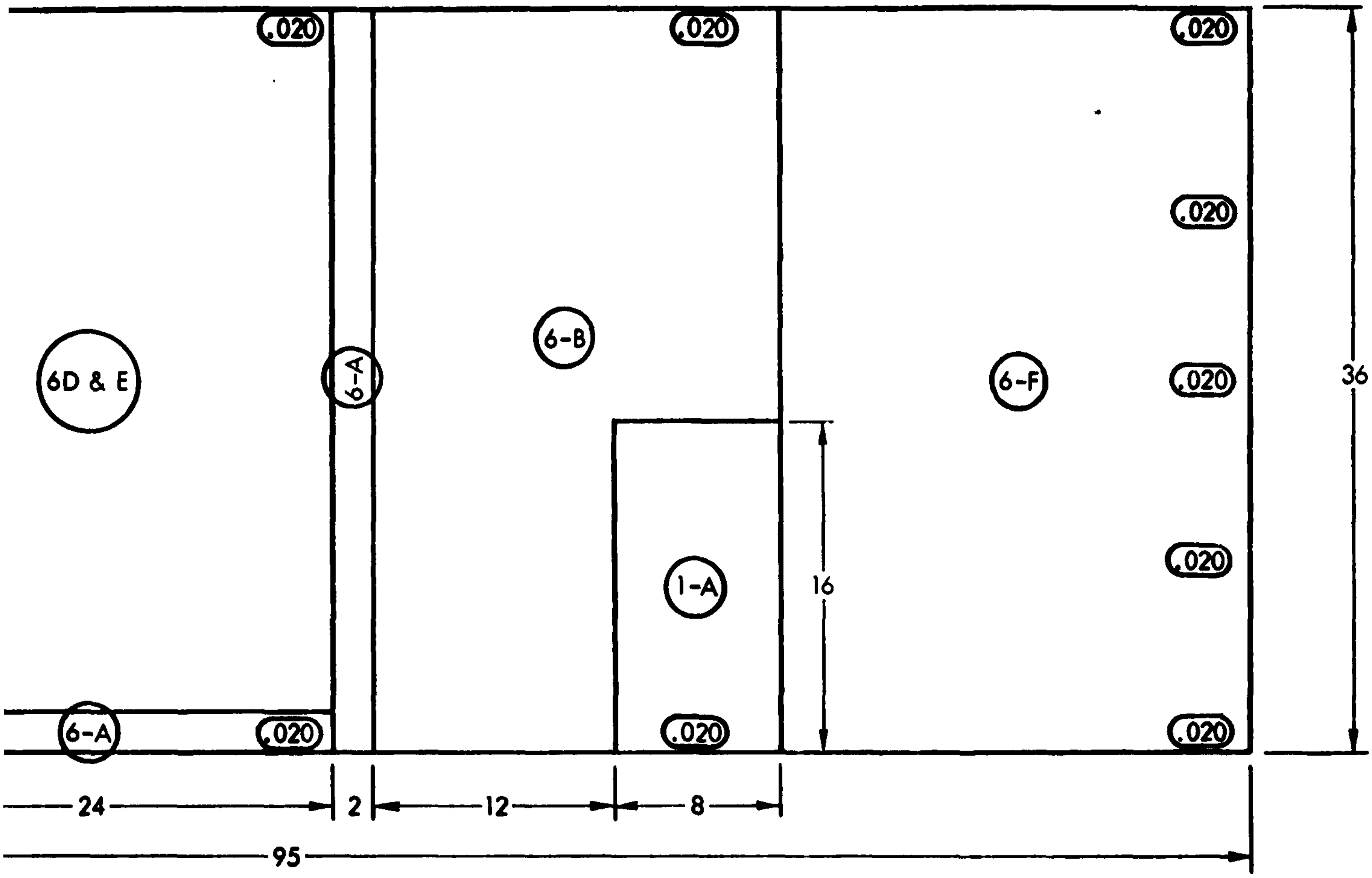
4 FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

5

6

THICKNESS MEASUREMENTS	SURFACE CONDITION: WHITE CORROSIVE PRODU

INSPECTION AND LAYOUT PRINT FT-1-61



2

T CODES

WELD

\

ELD

ING PROCEDURE

CTS OF CHEMISTRY

P PROPERTIES

5 MACHINABILITY

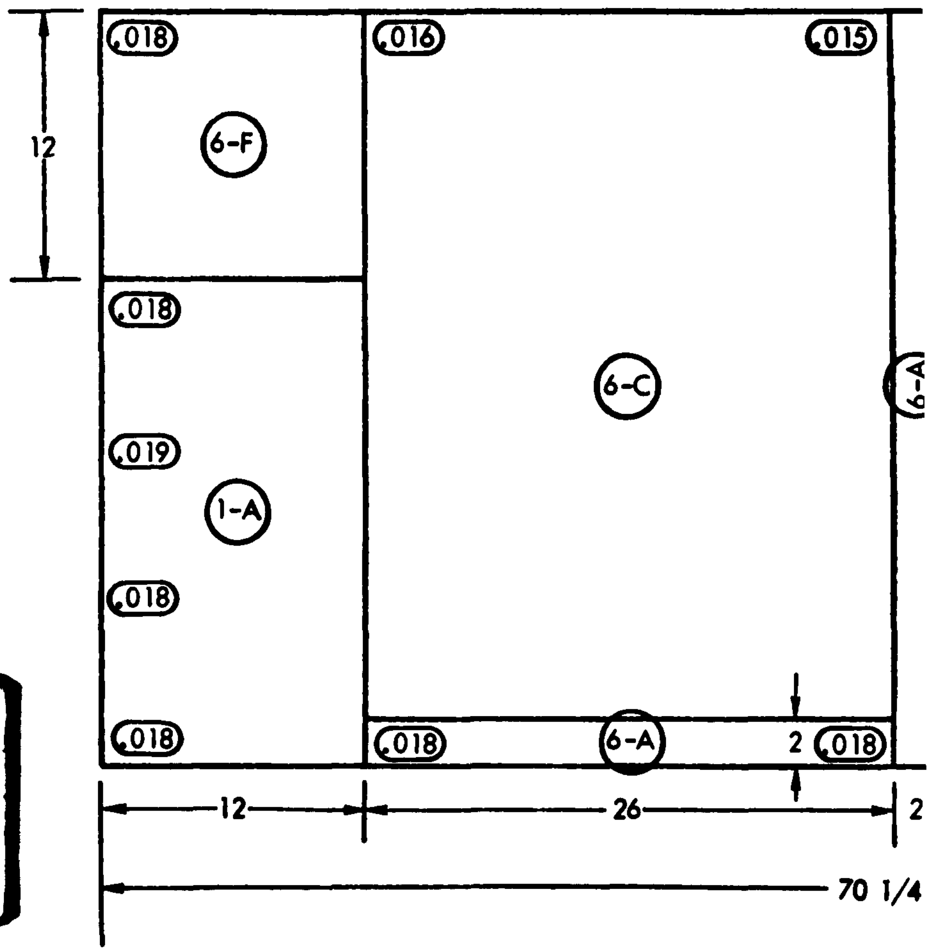
6 FORMABILITY

- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

WHITE CORROSIVE PRODUCT BOTH SIDES.

MATERIAL DATA	
ALLOY	7A1.-12Zr.
NOMINAL GAGE	.020
ACTUAL GAGE	.020-.022
ACTUAL SIZE	36 X 95
HEAT NO.	V1786T
SHEET NO.	4
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYO

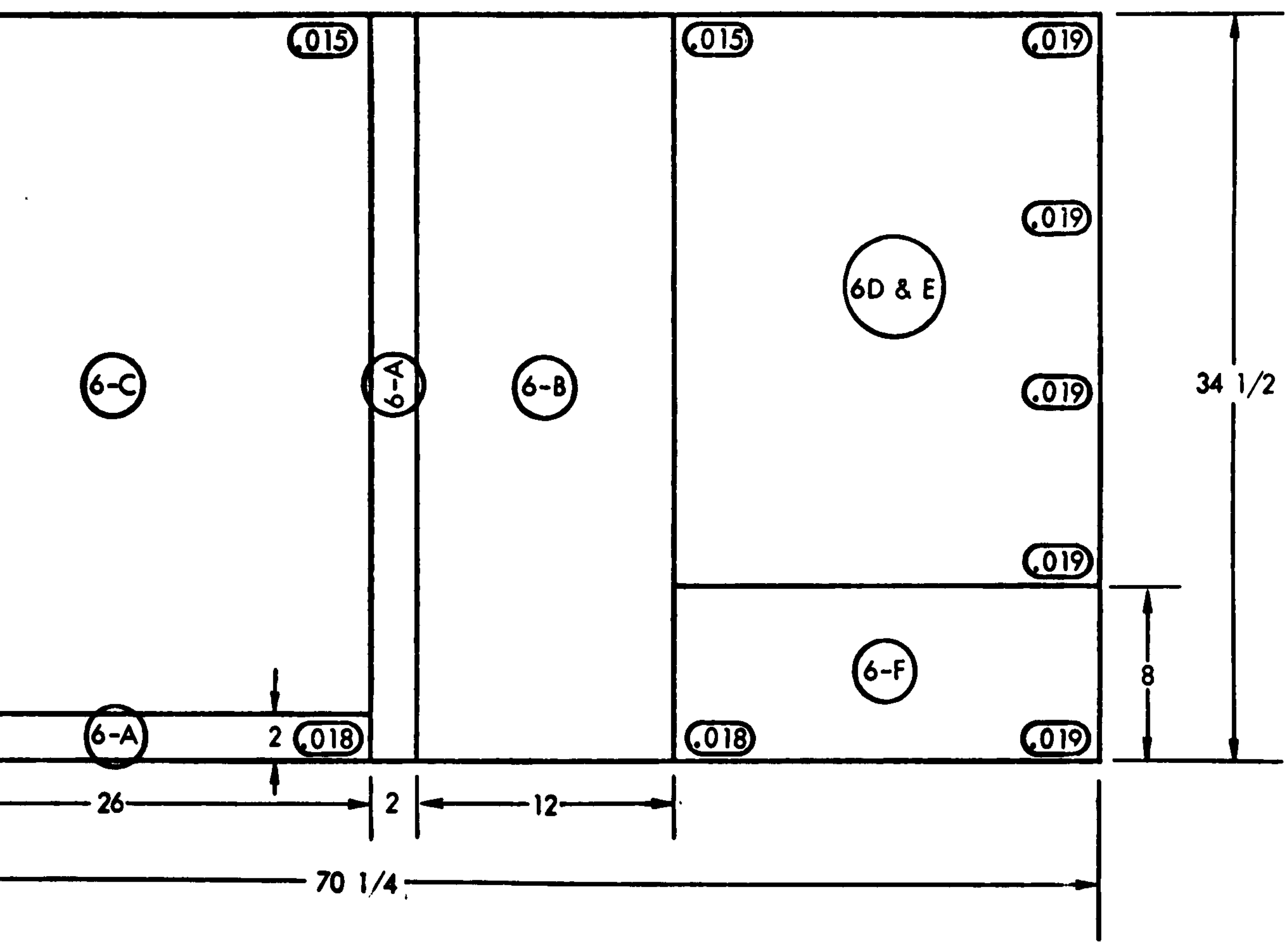


1

TEST CODES

1. MECHANICAL PROPERTIES
   - 1-A ROOM TEMPERATURE
   - 1-B ROOM & ELEVATED TEMPERATURE
   - 1-C CREEP PROPERTIES
2. SURFACE CONTAMINATION
   - 2-A BEND AND TENSILE
   - 2-B FATIGUE
   - 2-C FABRICATION PRACTICES
3. RESISTANT WELD
   - 3-A SPOT
   - 3-B SEAM
4. FUSION WELD
   - 4-A WELDING PROCEDURE
   - 4-B AFFECTS OF CHEMISTRY
   - 4-C CREEP PROPERTIES
5.
6.

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTA



2

T CODES

WELD

ELD

ING PROCEDURE

CTS OF CHEMISTRY

P PROPERTIES

5 MACHINABILITY

6 FORMABILITY

6-A BEND AND SURFACE

6-B BEND AND JOGGLE

6-C BEND AND STRETCH

6-D HYDRO PRESS

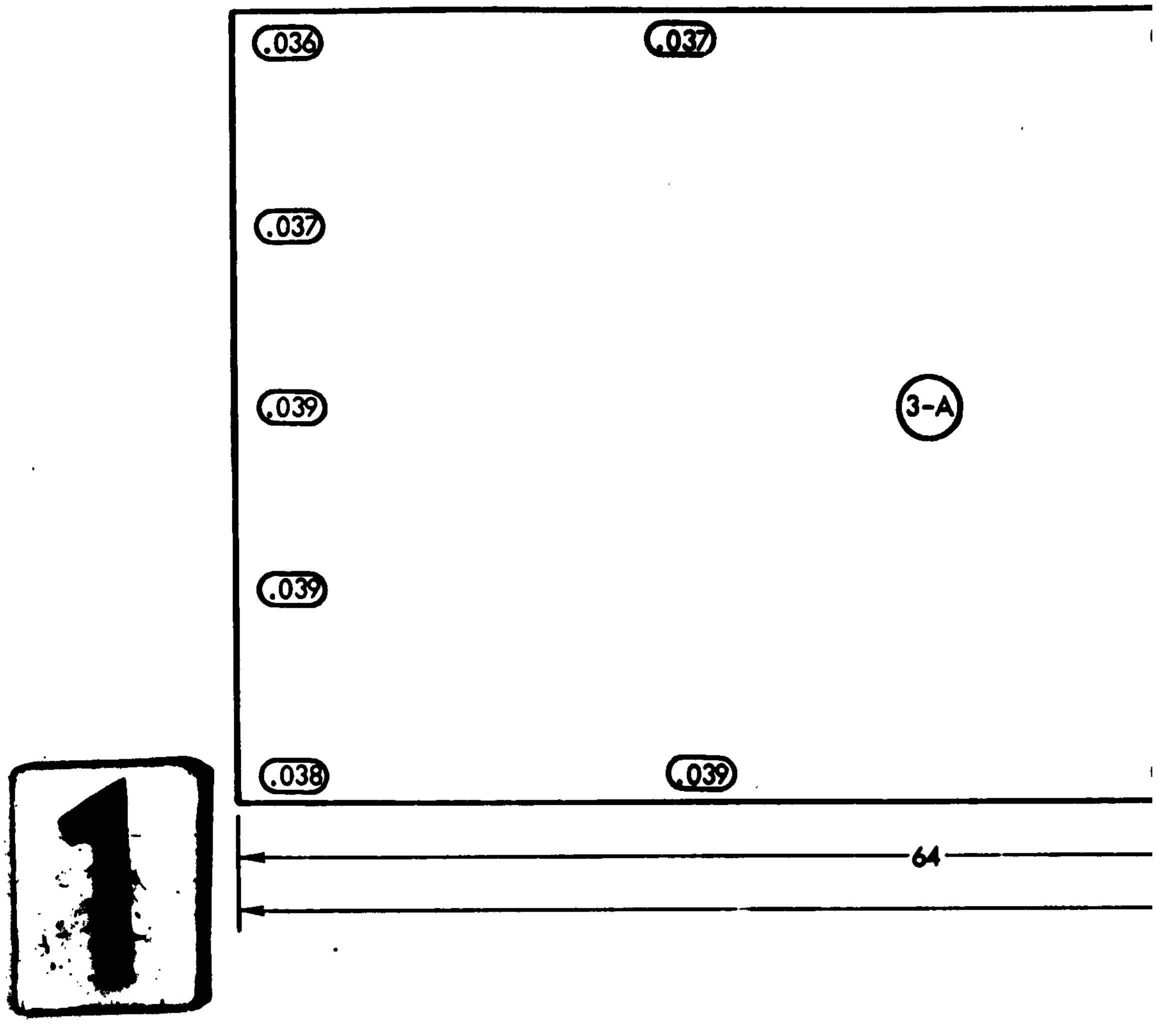
6-E HOT SIZE

6-F DIMPLE

PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	7Al.-12Zr
NOMINAL GAGE	.020
ACTUAL GAGE	.015 - .019
ACTUAL SIZE	34 1/2 x 70 1/4
HEAT NO.	32558
SHEET NO.	3174-4
FLATNESS	LESS THAN 1%
VENDOR	R.M.I.

INSPECTIO[N]



TEST CODES

1 MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

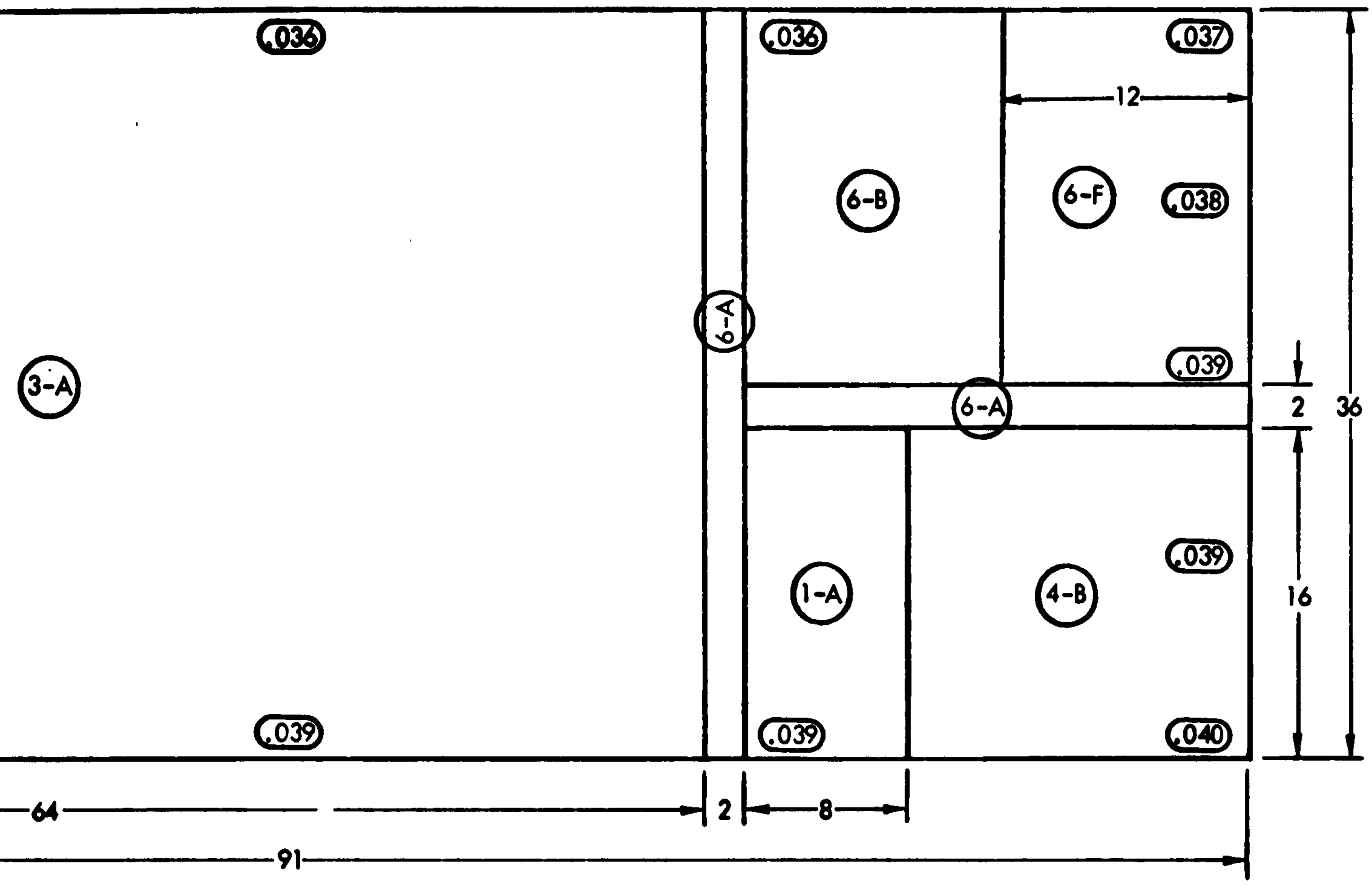
2 SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

3 RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

4 FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTR[Y]
- 4-C CREEP PROPERTIES

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION

INSPECTION AND LAYOUT PRINT FT-1-63



2

TEST CODES

NT WELD
OT
AM
 WELD
ELDING PROCEDURE
FECTS OF CHEMISTRY
EEP PROPERTIES

5 MACHINABILITY

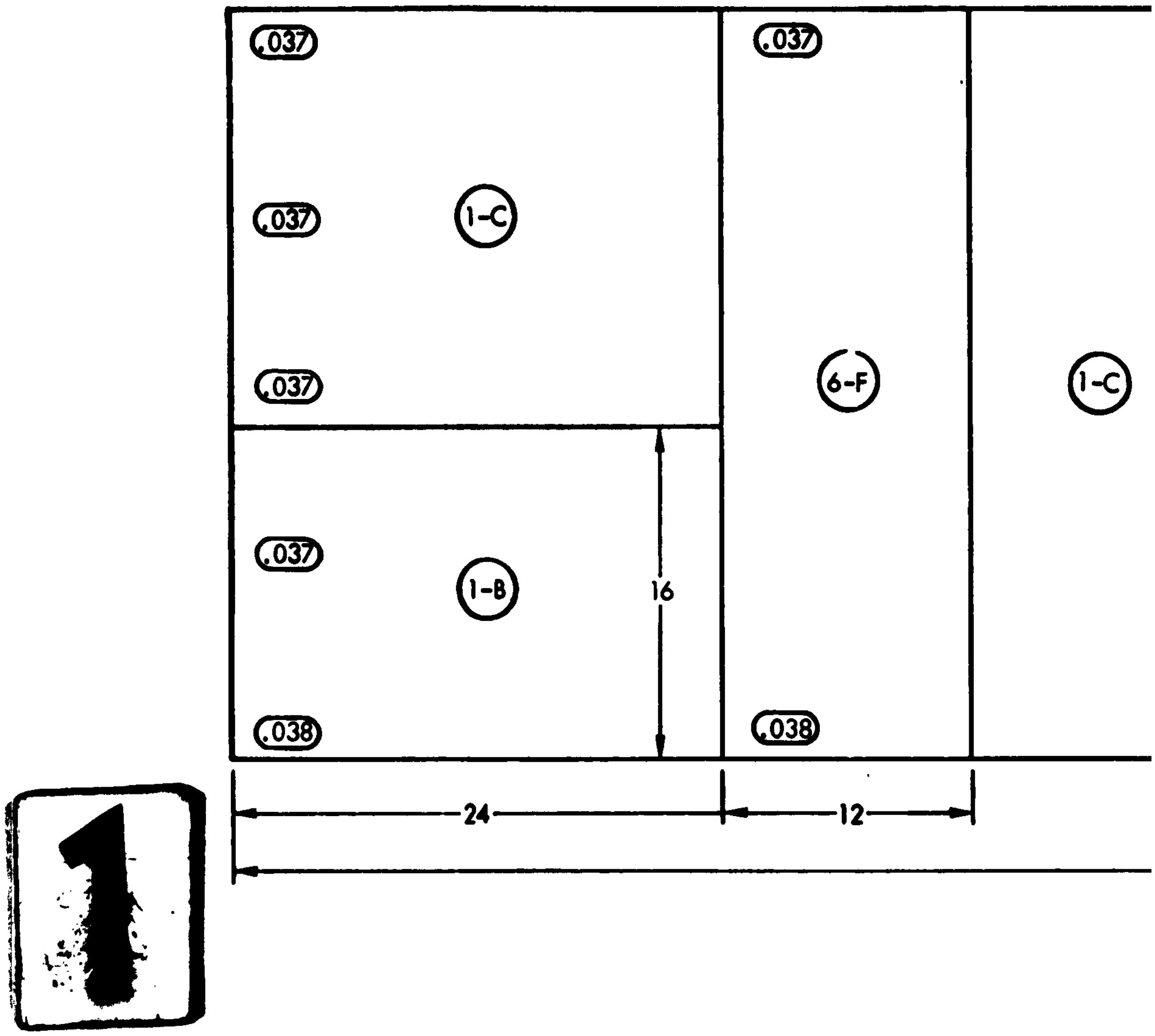
6 FORMABILITY

- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

ON: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	7A1.-12Zr.
NOMINAL GAGE	.040
ACTUAL GAGE	.036-.040
ACTUAL SIZE	36 x 91
HEAT NO.	V1787M
SHEET NO.	5
FLATNESS	1%
VENDOR	TMCA

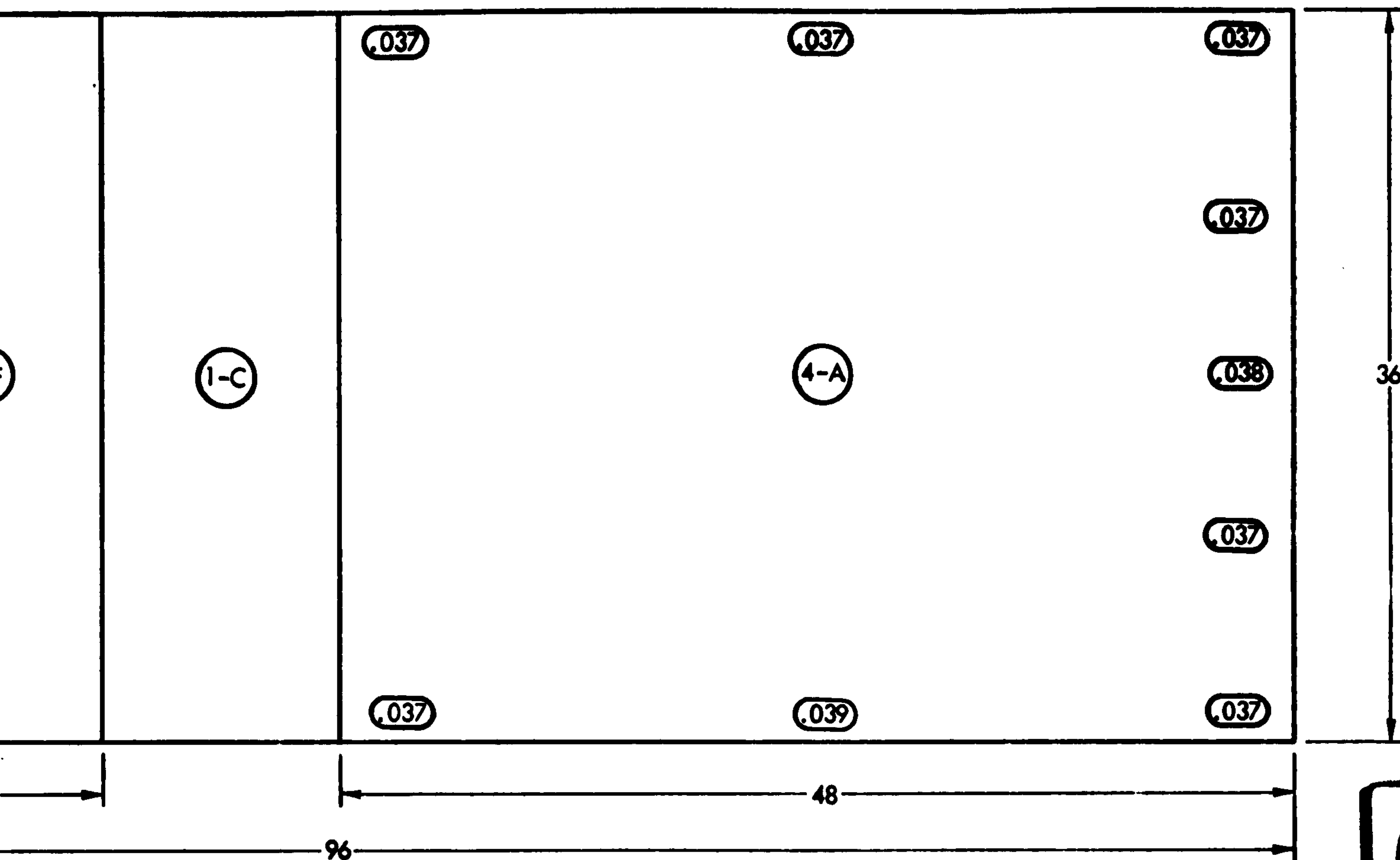
INSPECTION



TEST CODES

1. MECHANICAL PROPERTIES
   - 1-A ROOM TEMPERATURE
   - 1-B ROOM & ELEVATED TEMPERATURE
   - 1-C CREEP PROPERTIES
2. SURFACE CONTAMINATION
   - 2-A BEND AND TENSILE
   - 2-B FATIGUE
   - 2-C FABRICATION PRACTICES
3. RESISTANT WELD
   - 3-A SPOT
   - 3-B SEAM
4. FUSION WELD
   - 4-A WELDING PROCEDURE
   - 4-B AFFECTS OF CHEMISTRY
   - 4-C CREEP PROPERTIES

THICKNESS MEASUREMENTS	SURFACE CONDITION: WHITE CORROS SLIGHT GRIND



2

EST CODES

NT WELD
OT
AM
WELD
LDING PROCEDURE
FECTS OF CHEMISTRY
EEP PROPERTIES

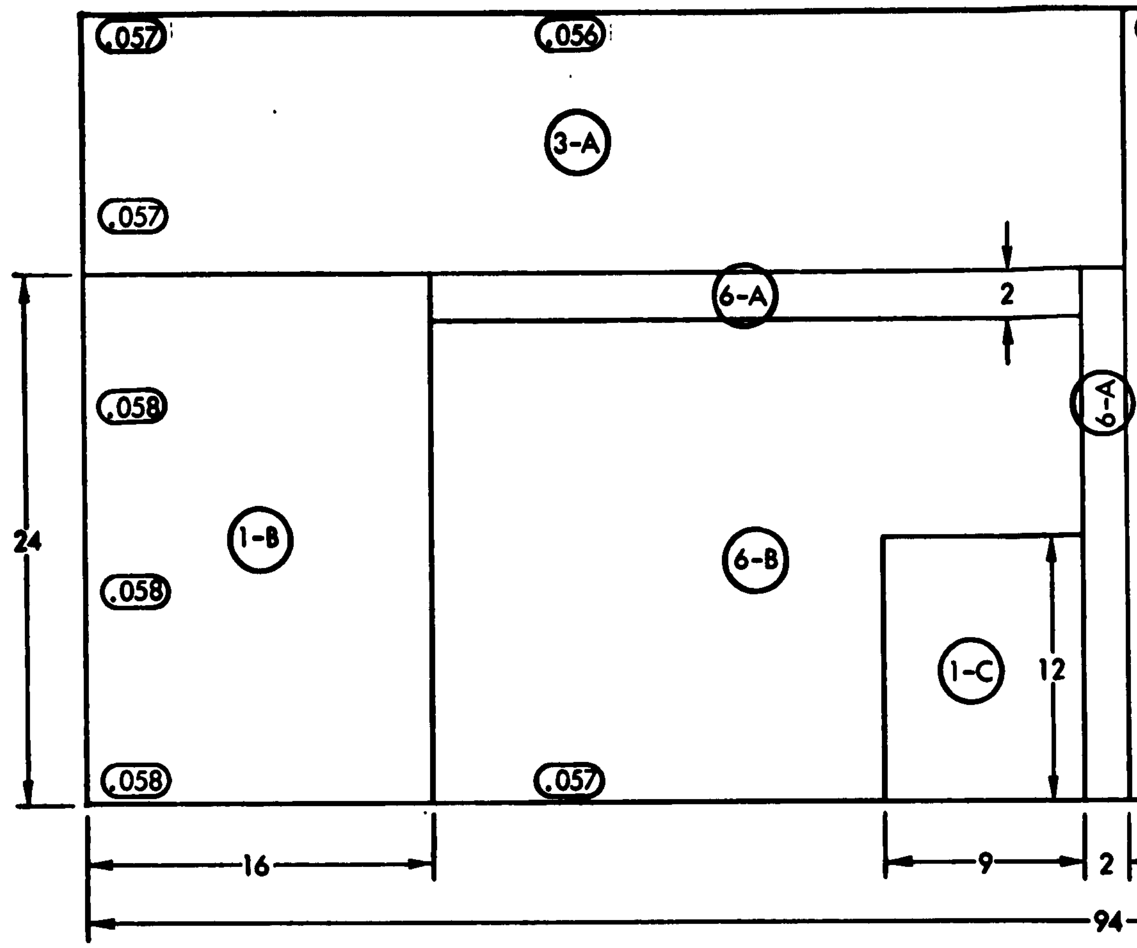
5 MACHINABILITY

6 FORMABILITY
- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

N: WHITE CORROSIVE PRODUCT ON BOTH SIDES.
SLIGHT GRIND MARKS ONE SIDE.

MATERIAL DATA	
ALLOY	7Al.-12Zr.
NOMINAL GAGE	.040
ACTUAL GAGE	.037-.039
ACTUAL SIZE	36 X 96
HEAT NO.	V1788T
SHEET NO.	3
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOU



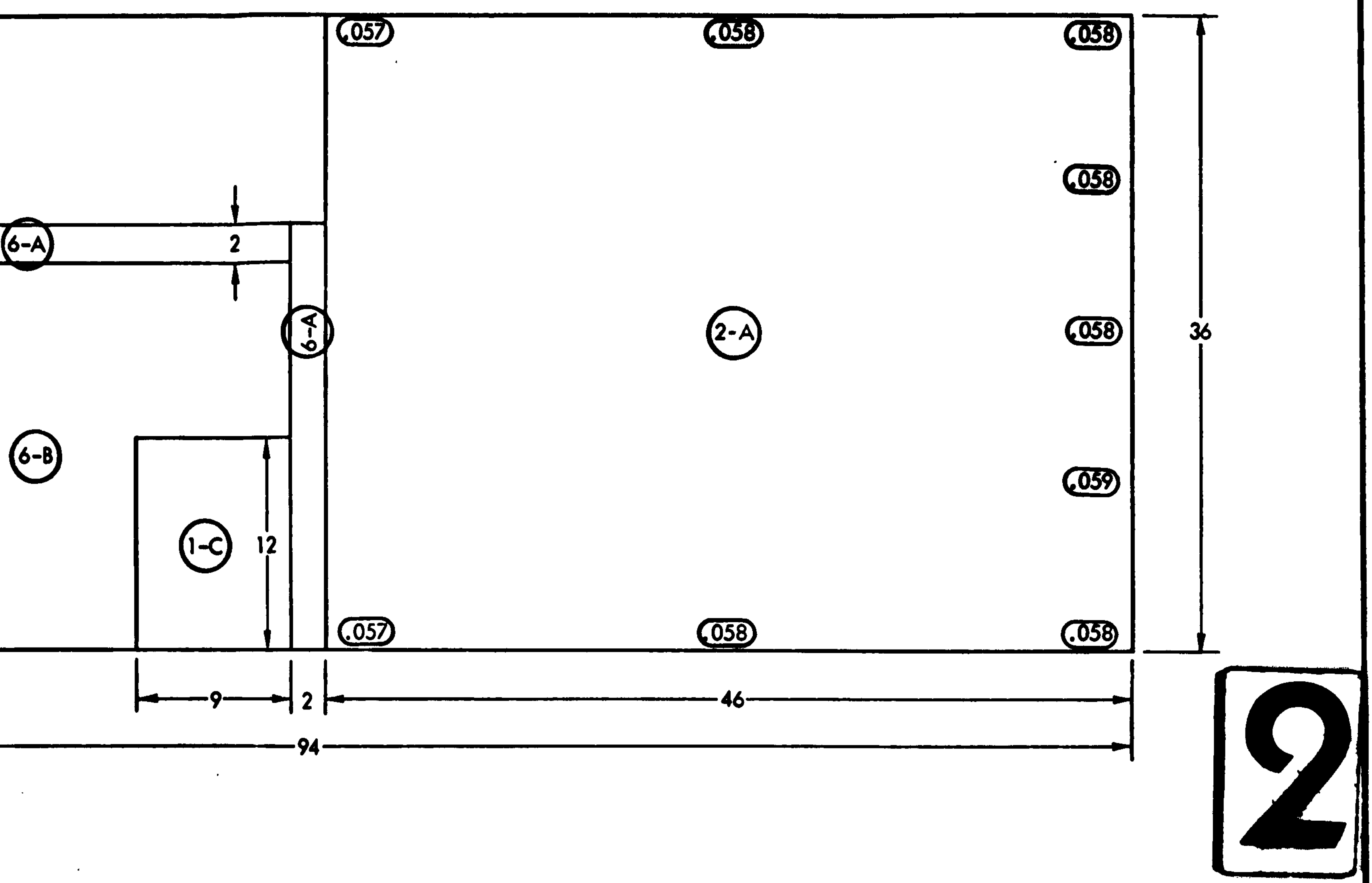
1

TEST CODES

1. MECHANICAL PROPERTIES
   - 1-A ROOM TEMPERATURE
   - 1-B ROOM & ELEVATED TEMPERATURE
   - 1-C CREEP PROPERTIES
2. SURFACE CONTAMINATION
   - 2-A BEND AND TENSILE
   - 2-B FATIGUE
   - 2-C FABRICATION PRACTICES
3. RESISTANT WELD
   - 3-A SPOT
   - 3-B SEAM
4. FUSION WELD
   - 4-A WELDING PROCEDURE
   - 4-B AFFECTS OF CHEMISTRY
   - 4-C CREEP PROPERTIES
5.
6.

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE

INSPECTION AND LAYOUT PRINT FT-1-66



EST CODES

IT WELD
OT
M
WELD
LDING PROCEDURE
ECTS OF CHEMISTRY
EP PROPERTIES

5 MACHINABILITY

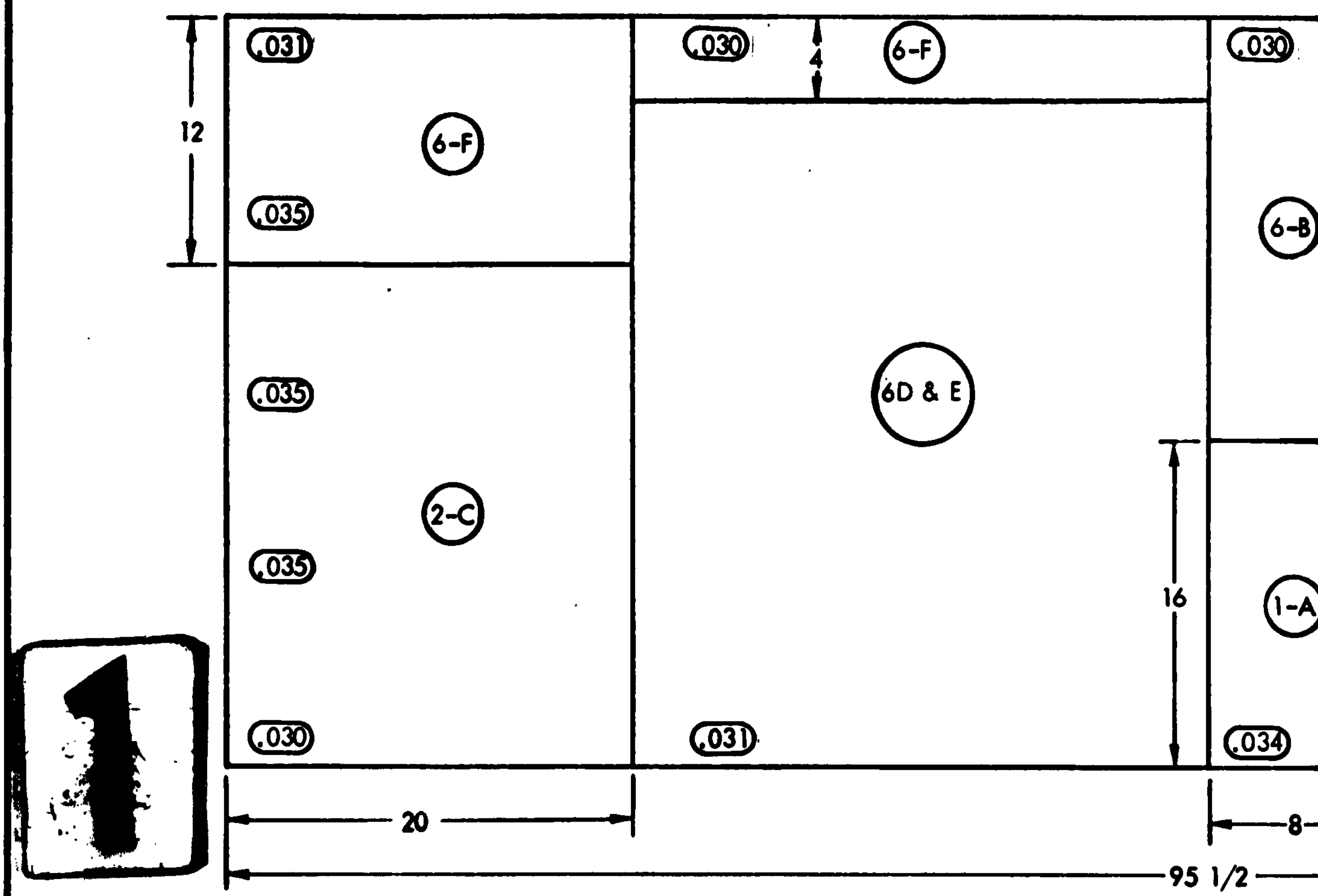
6 FORMABILITY

6-A BEND AND SURFACE
6-B BEND AND JOGGLE
6-C BEND AND STRETCH
6-D HYDRO PRESS
6-E HOT SIZE
6-F DIMPLE

N: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	7Al. - 12Zr.
NOMINAL GAGE	.062
ACTUAL GAGE	.056 - .059
ACTUAL SIZE	36 x 94
HEAT NO.	V1786M
SHEET NO.	3
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOUT

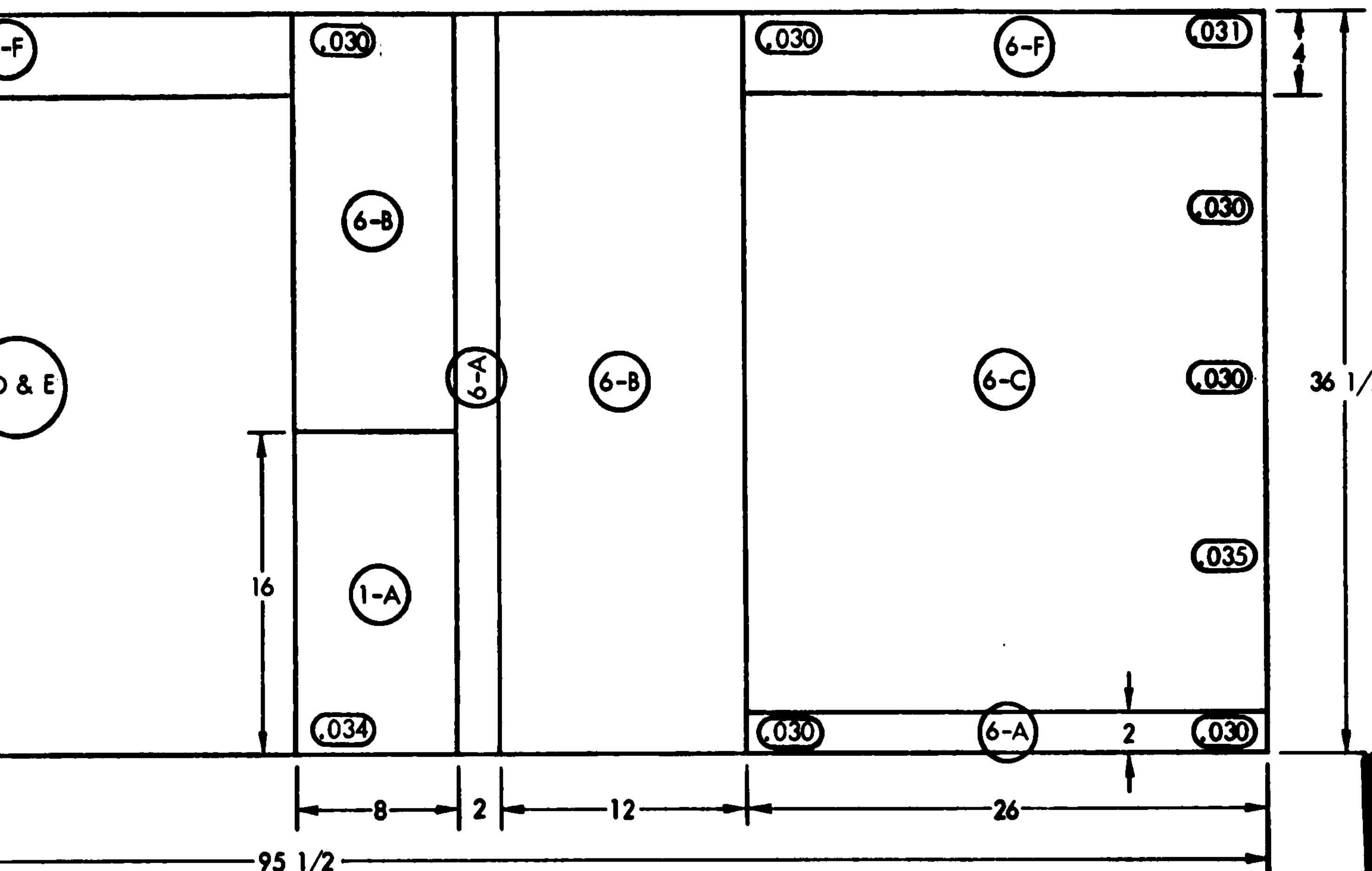


TEST CODES

1. MECHANICAL PROPERTIES
   - 1-A ROOM TEMPERATURE
   - 1-B ROOM & ELEVATED TEMPERATURE
   - 1-C CREEP PROPERTIES
2. SURFACE CONTAMINATION
   - 2-A BEND AND TENSILE
   - 2-B FATIGUE
   - 2-C FABRICATION PRACTICES
3. RESISTANT WELD
   - 3-A SPOT
   - 3-B SEAM
4. FUSION WELD
   - 4-A WELDING PROCEDURE
   - 4-B AFFECTS OF CHEMISTRY
   - 4-C CREEP PROPERTIES
5.
6.

⬭ THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE

INSPECTION AND LAYOUT PRINT FT-1-65



2

T CODES

WELD
T
M
ELD
DING PROCEDURE
CTS OF CHEMISTRY
P PROPERTIES

(5) MACHINABILITY

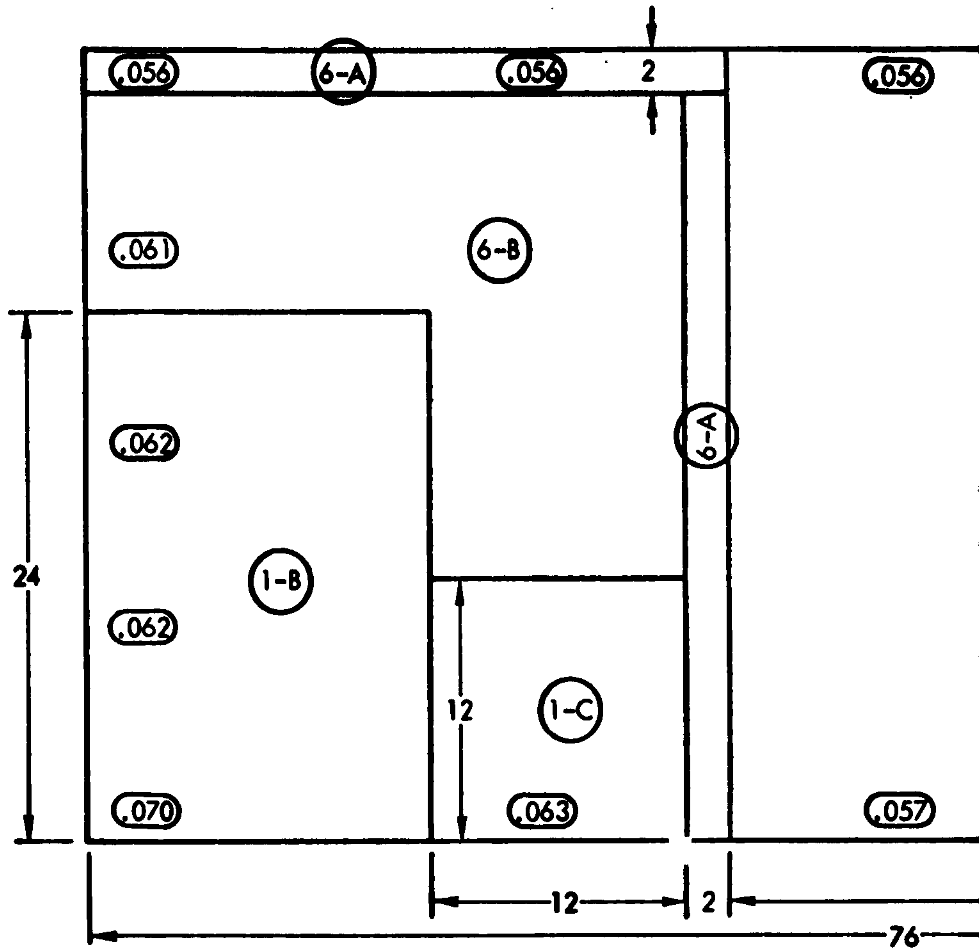
(6) FORMABILITY

- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	7Al. - 12Zr.
NOMINAL GAGE	.040
ACTUAL GAGE	.030 - .035
ACTUAL SIZE	36-1/2 x 95-1/2
HEAT NO.	32558
SHEET NO.	3175-5
FLATNESS	LESS THAN 1%
VENDOR	R.M.I.

INSPECTION AND LAYOUT



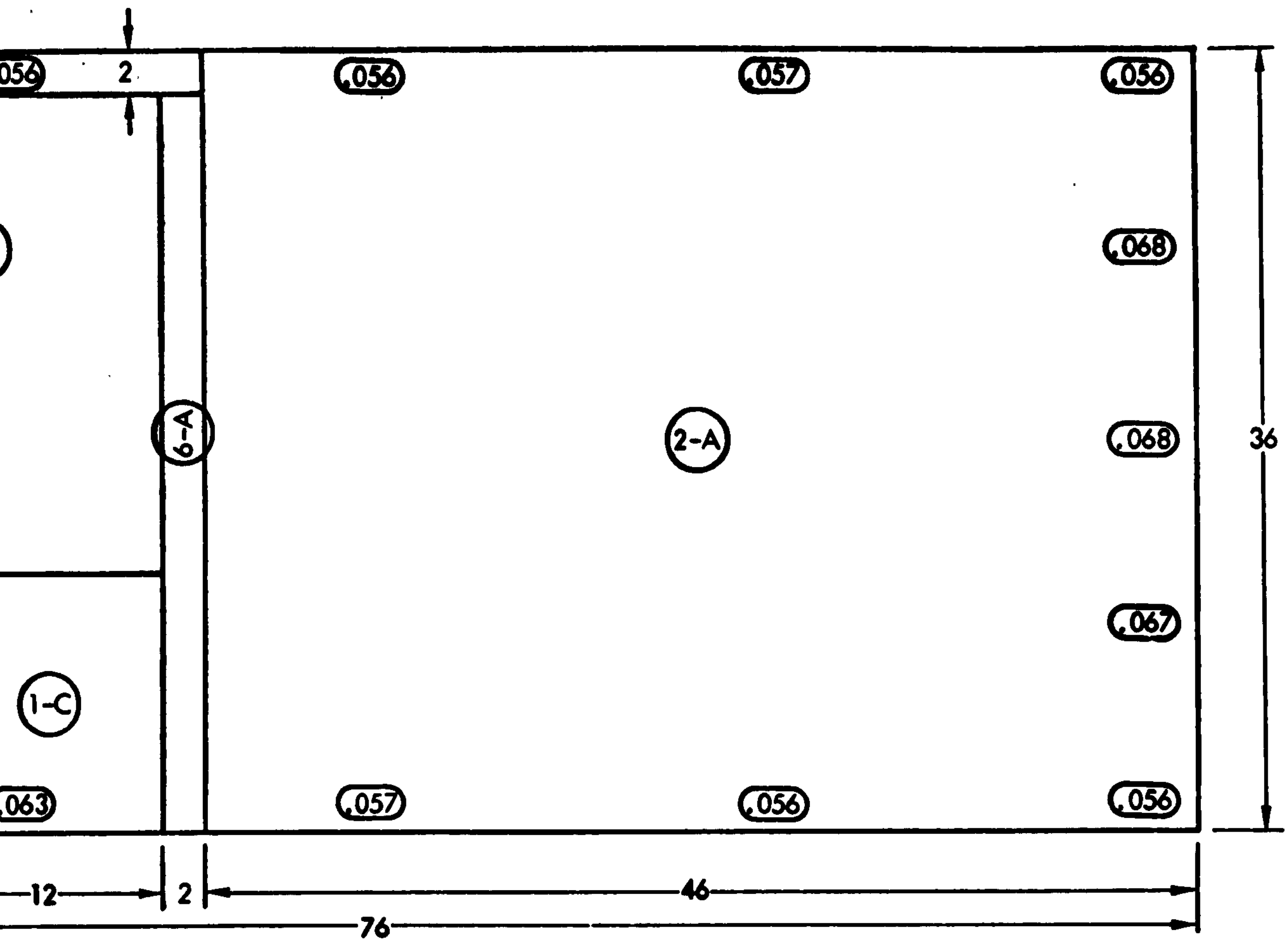
1

TEST CODES

1. MECHANICAL PROPERTIES
   - 1-A ROOM TEMPERATURE
   - 1-B ROOM & ELEVATED TEMPERATURE
   - 1-C CREEP PROPERTIES
2. SURFACE CONTAMINATION
   - 2-A BEND AND TENSILE
   - 2-B FATIGUE
   - 2-C FABRICATION PRACTICES
3. RESISTANT WELD
   - 3-A SPOT
   - 3-B SEAM
4. FUSION WELD
   - 4-A WELDING PROCEDURE
   - 4-B AFFECTS OF CHEMISTRY
   - 4-C CREEP PROPERTIES
5.
6.

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE

INSPECTION AND LAYOUT PRINT FT-1-67



2

EST CODES

NT WELD
OT
AM
WELD
LDING PROCEDURE
FECTS OF CHEMISTRY
EEP PROPERTIES

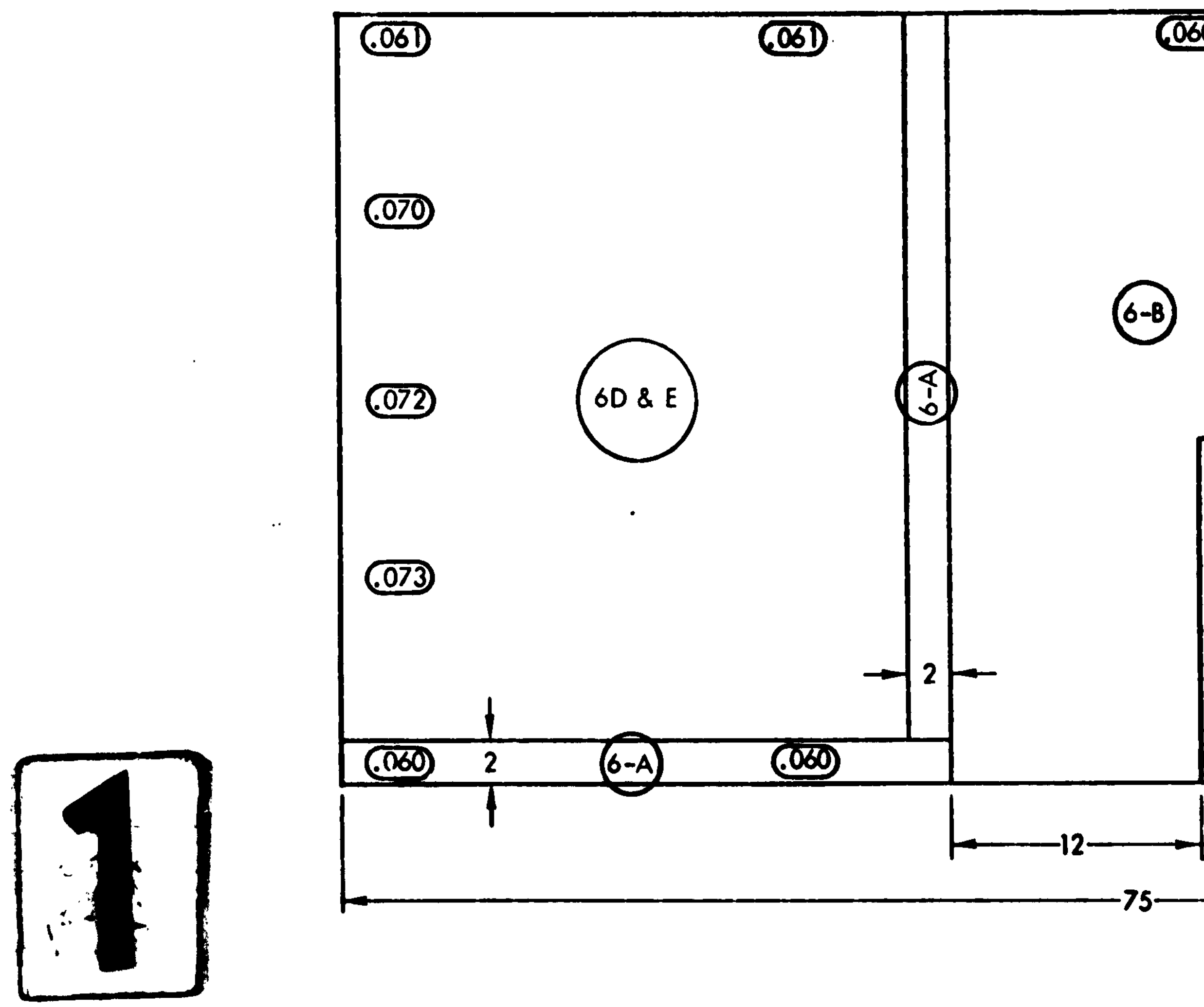
5 MACHINABILITY

6 FORMABILITY
- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

N: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	7Al. - 12Zr.
NOMINAL GAGE	.062
ACTUAL GAGE	.056 - .070
ACTUAL SIZE	36 x 76
HEAT NO.	32558
SHEET NO.	3176-8
FLATNESS	LESS THAN 1%
VENDOR	R.M.I.

INSPECTION AND LAYOU



TEST CODES

1 MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

2 SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICLS

3 RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

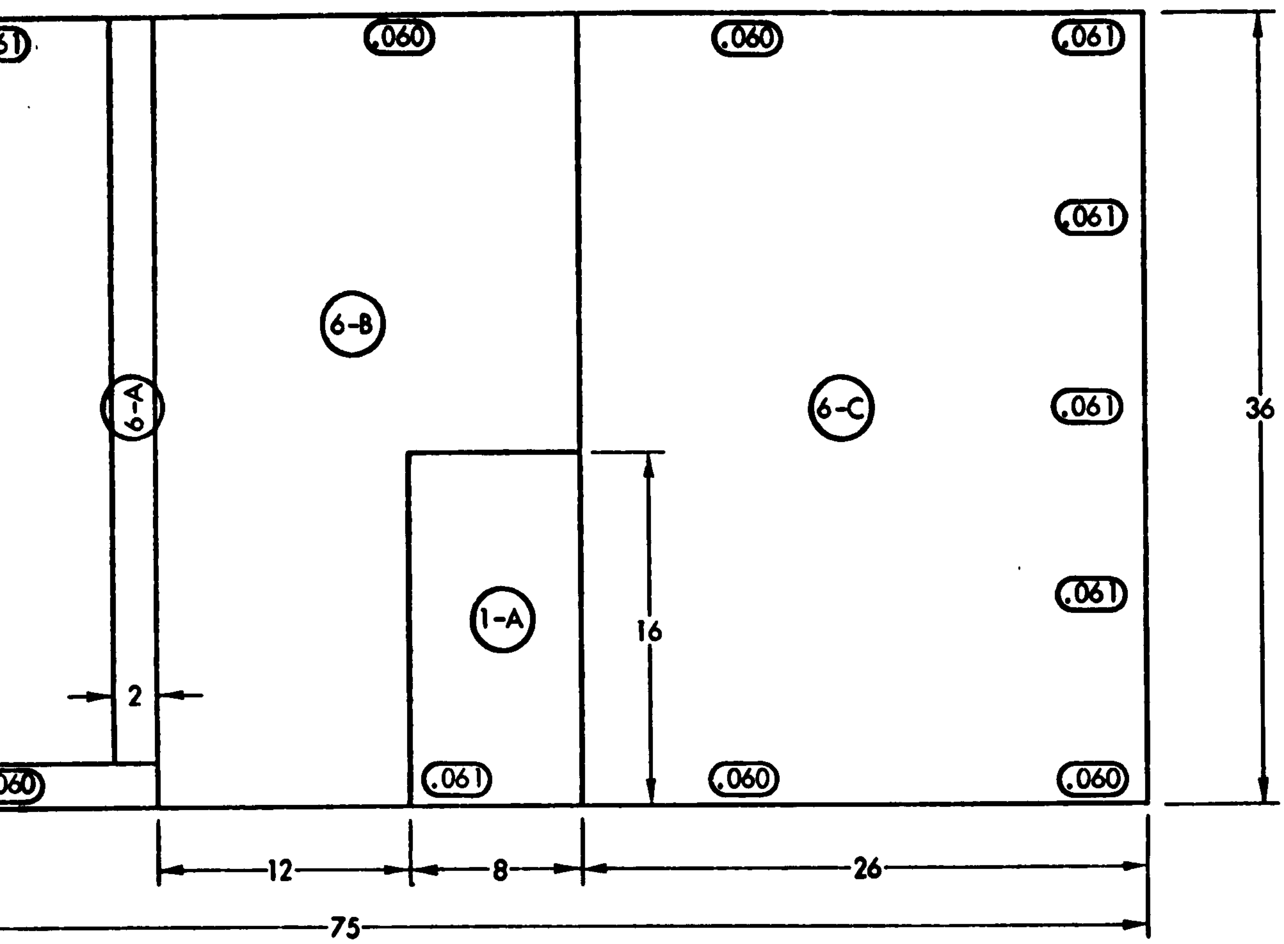
4 FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

5

6

THICKNESS MEASUREMENTS	SURFACE CONDITION: – PRODUCTION ACCEPTAB

INSPECTION AND LAYOUT PRINT FT-1-68



2

ST CODES

T WELD

T

M

VELD

DING PROCEDURE

ECTS OF CHEMISTRY

EP PROPERTIES

5 MACHINABILITY

6 FORMABILITY

6-A BEND AND SURFACE

6-B BEND AND JOGGLE

6-C BEND AND STRETCH

6-D HYDRO PRESS

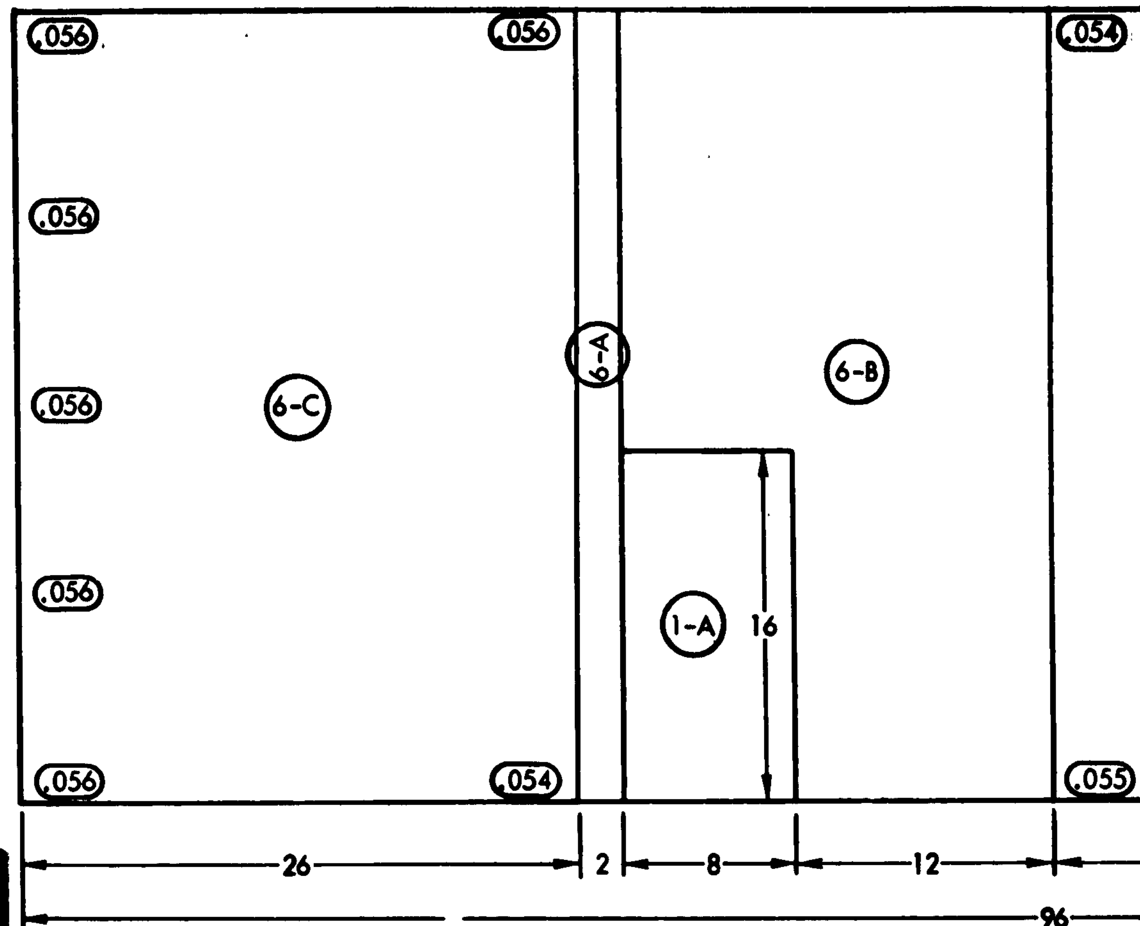
6-E HOT SIZE

6-F DIMPLE

: -- PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	7Al. - 12Zr.
NOMINAL GAGE	.062
ACTUAL GAGE	.060 - .073
ACTUAL SIZE	36 x 75
HEAT NO.	32885
SHEET NO.	3176-4
FLATNESS	LESS THAN 1%
VENDOR	R.M.I.

INSPECTION AND LAYO



1

TEST CODES

(1) MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

(2) SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

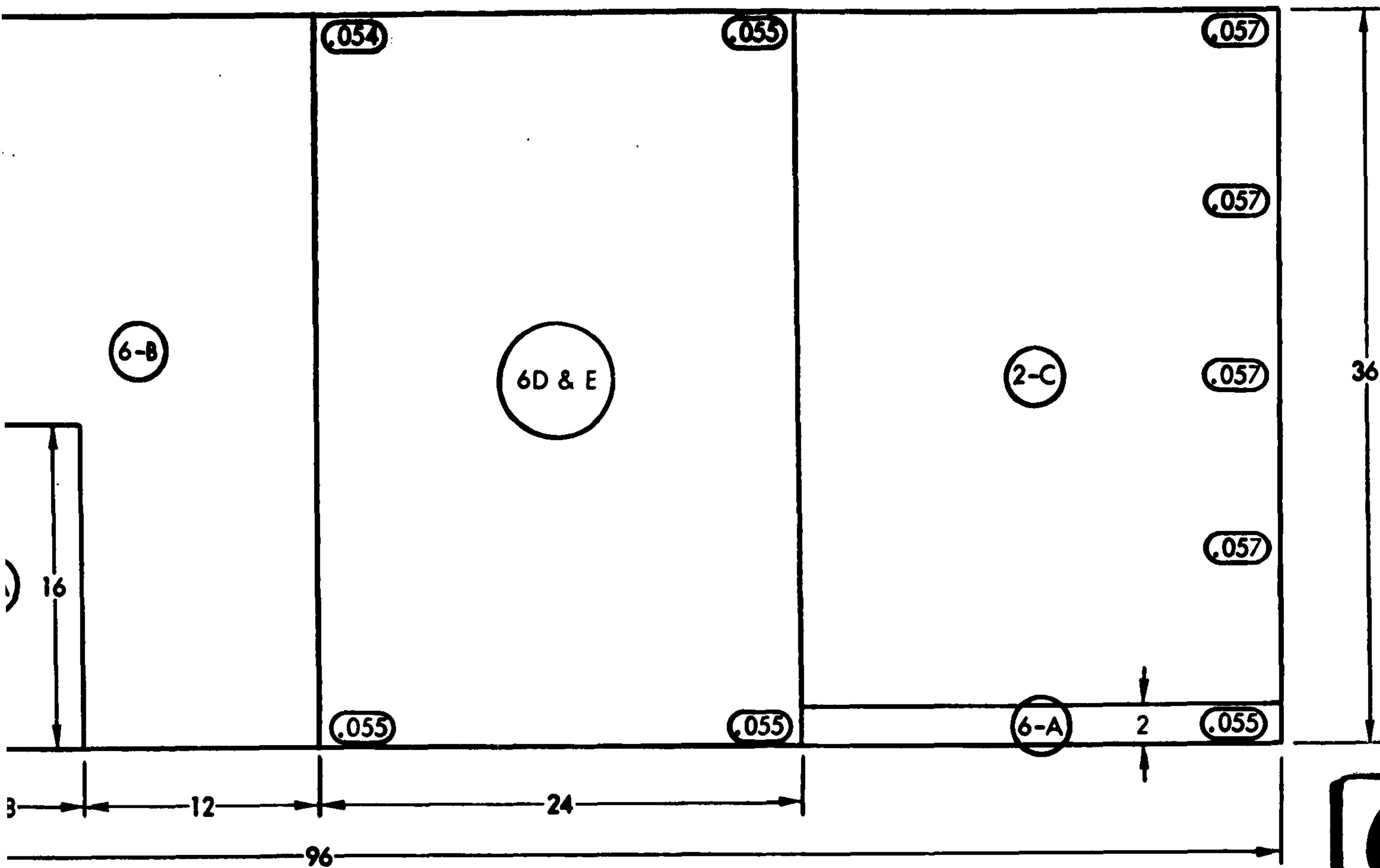
(3) RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

(4) FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

(5)

(6)

⬭ THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE



2

EST CODES

IT WELD
OT
AM
WELD
LDING PROCEDURE
ECTS OF CHEMISTRY
EEP PROPERTIES

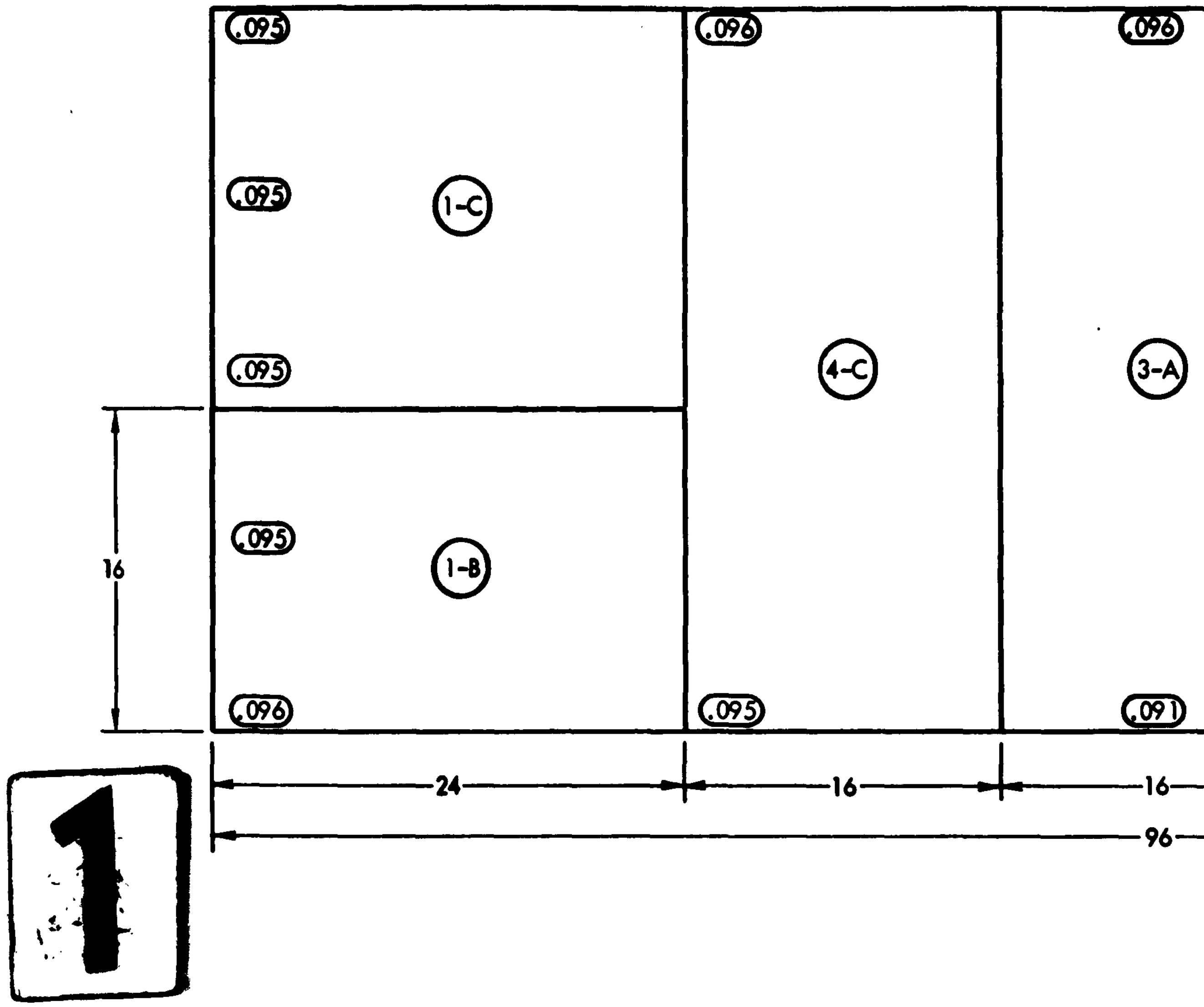
5 MACHINABILITY

6 FORMABILITY
- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

N: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	7Al. - 12Zr.
NOMINAL GAGE	.062
ACTUAL GAGE	.054 - .057
ACTUAL SIZE	36 x 96
HEAT NO.	V1786M
SHEET NO.	4
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOU



TEST CODES

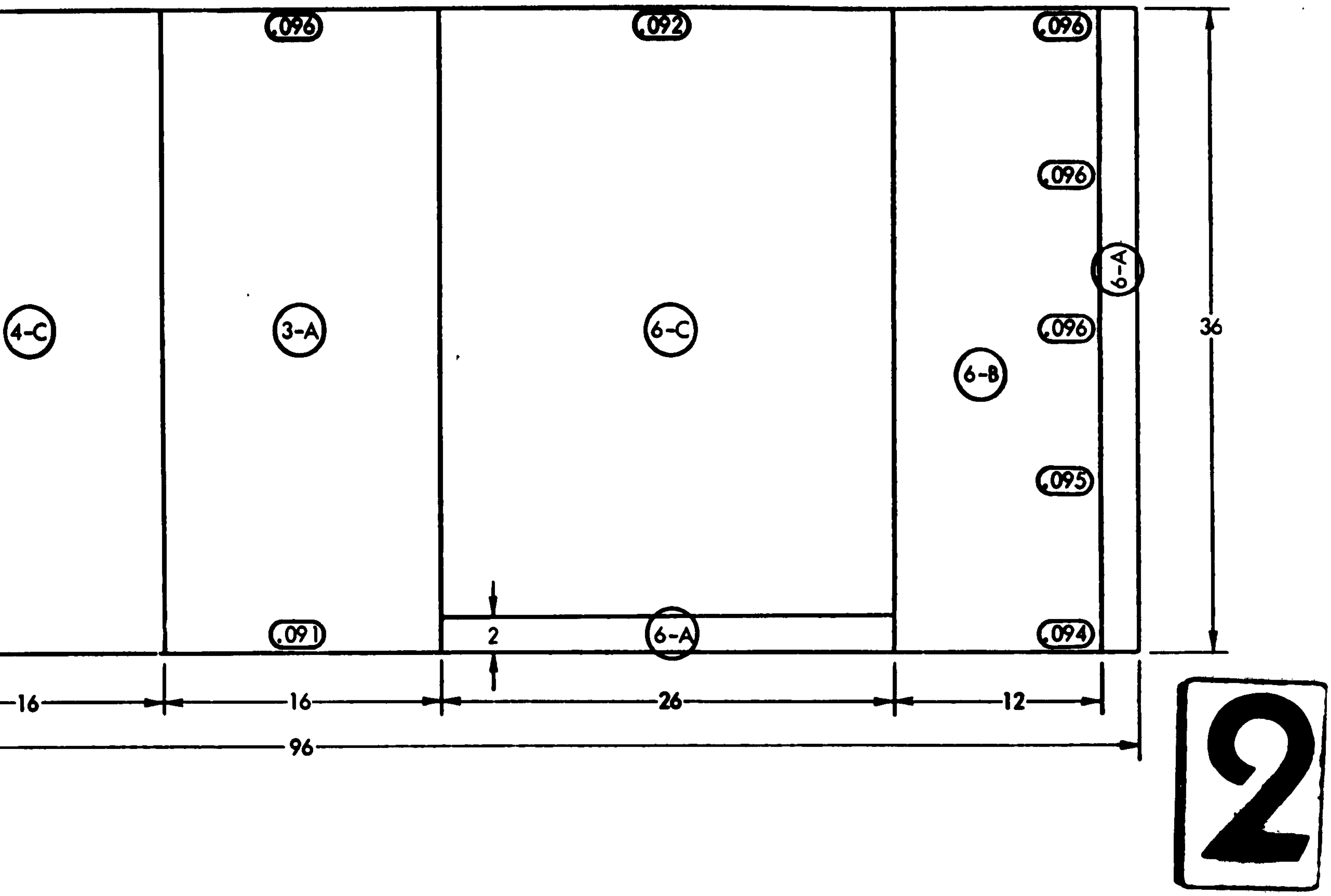
1. MECHANICAL PROPERTIES
   - 1-A ROOM TEMPERATURE
   - 1-B ROOM & ELEVATED TEMPERATURE
   - 1-C CREEP PROPERTIES
2. SURFACE CONTAMINATION
   - 2-A BEND AND TENSILE
   - 2-B FATIGUE
   - 2-C FABRICATION PRACTICES
3. RESISTANT WELD
   - 3-A SPOT
   - 3-B SEAM
4. FUSION WELD
   - 4-A WELDING PROCEDURE
   - 4-B AFFECTS OF CHEMISTRY
   - 4-C CREEP PROPERTIES

5

6

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE

INSPECTION AND LAYOUT PRINT FT-2-69



ST CODES

T WELD
OT
M

VELD
DING PROCEDURE
ECTS OF CHEMISTRY
EP PROPERTIES

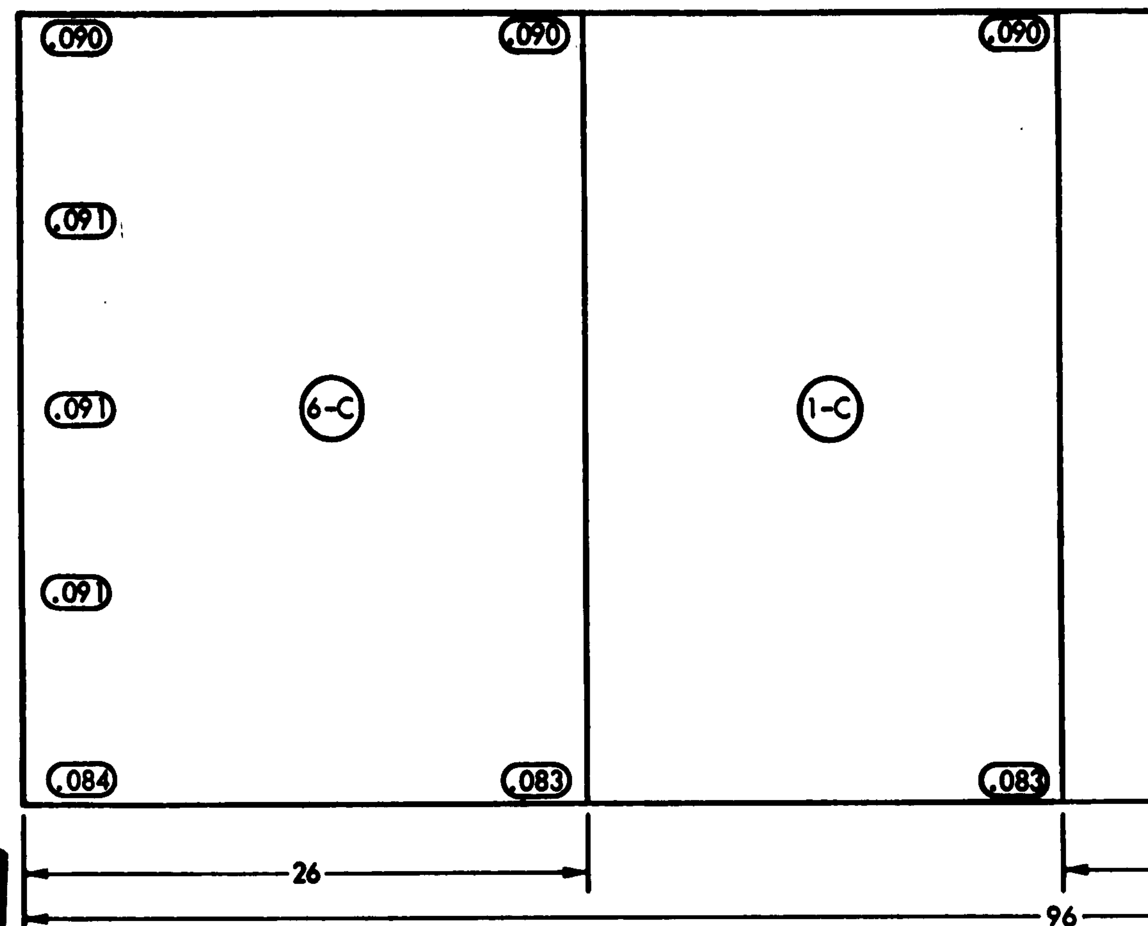
5 MACHINABILITY

6 FORMABILITY
6-A BEND AND SURFACE
6-B BEND AND JOGGLE
6-C BEND AND STRETCH
6-D HYDRO PRESS
6-E HOT SIZE
6-F DIMPLE

N: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	7Al. - 12Zr.
NOMINAL GAGE	.090
ACTUAL GAGE	.091 - .096
ACTUAL SIZE	36 x 96
HEAT NO.	V1787B
SHEET NO.	2
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOU



1

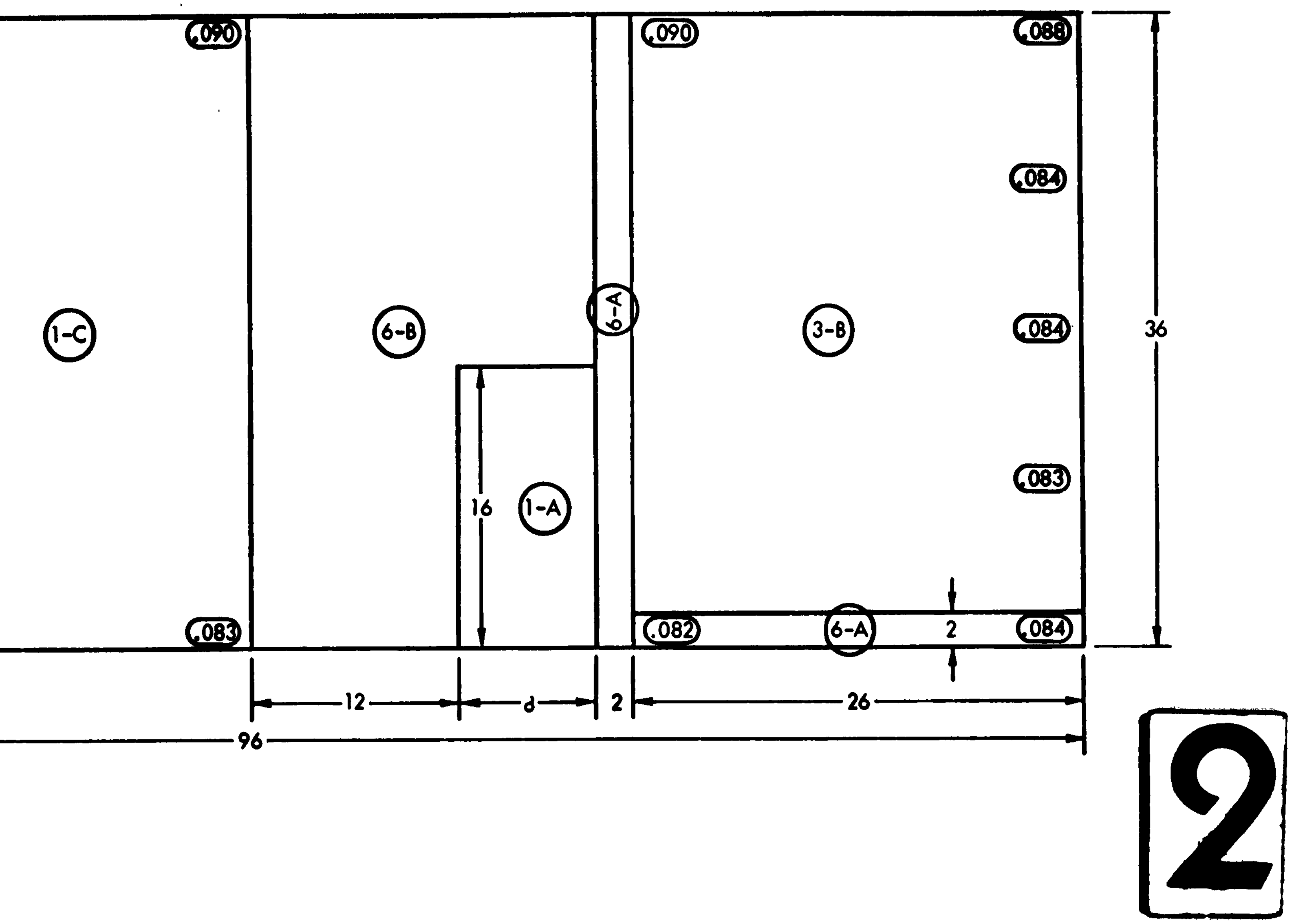
TEST CODES

1. MECHANICAL PROPERTIES
   - 1-A ROOM TEMPERATURE
   - 1-B ROOM & ELEVATED TEMPERATURE
   - 1-C CREEP PROPERTIES
2. SURFACE CONTAMINATION
   - 2-A BEND AND TENSILE
   - 2-B FATIGUE
   - 2-C FABRICATION PRACTICES
3. RESISTANT WELD
   - 3-A SPOT
   - 3-B SEAM
4. FUSION WELD
   - 4-A WELDING PROCEDURE
   - 4-B AFFECTS OF CHEMISTRY
   - 4-C CREEP PROPERTIES

5

6

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABL



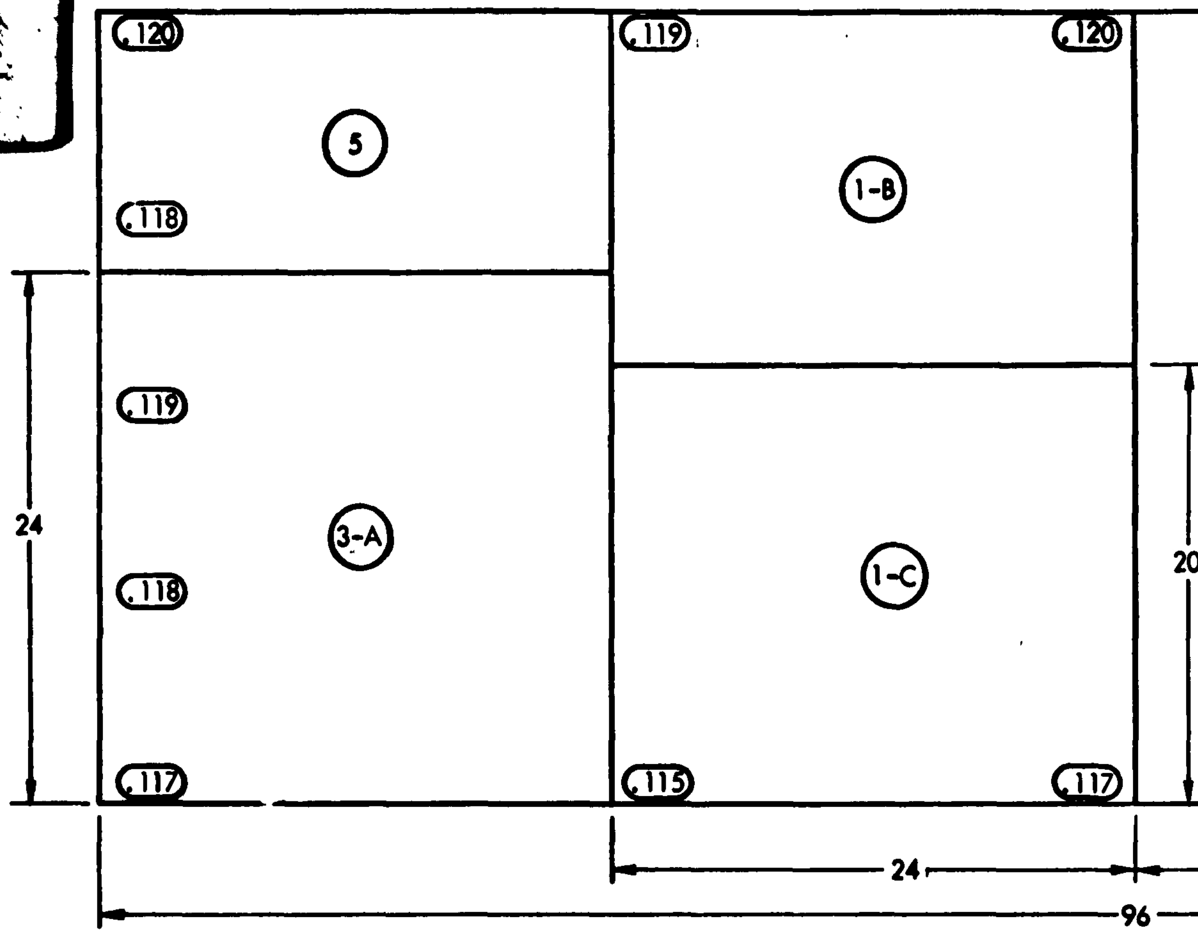
T CODES			
WELD	5	MACHINABILITY	
	6	FORMABILITY	
A		6-A	BEND AND SURFACE
ELD		6-B	BEND AND JOGGLE
DING PROCEDURE		6-C	BEND AND STRETCH
CTS OF CHEMISTRY		6-D	HYDRO PRESS
P PROPERTIES		6-E	HOT SIZE
		6-F	DIMPLE

PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	7Al. - 12Zr.
NOMINAL GAGE	.090
ACTUAL GAGE	.082 - .091
ACTUAL SIZE	36 x 96
HEAT NO.	V1787T
SHEET NO.	2
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOU

1



TEST CODES

(1) MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

(2) SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

(3) RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

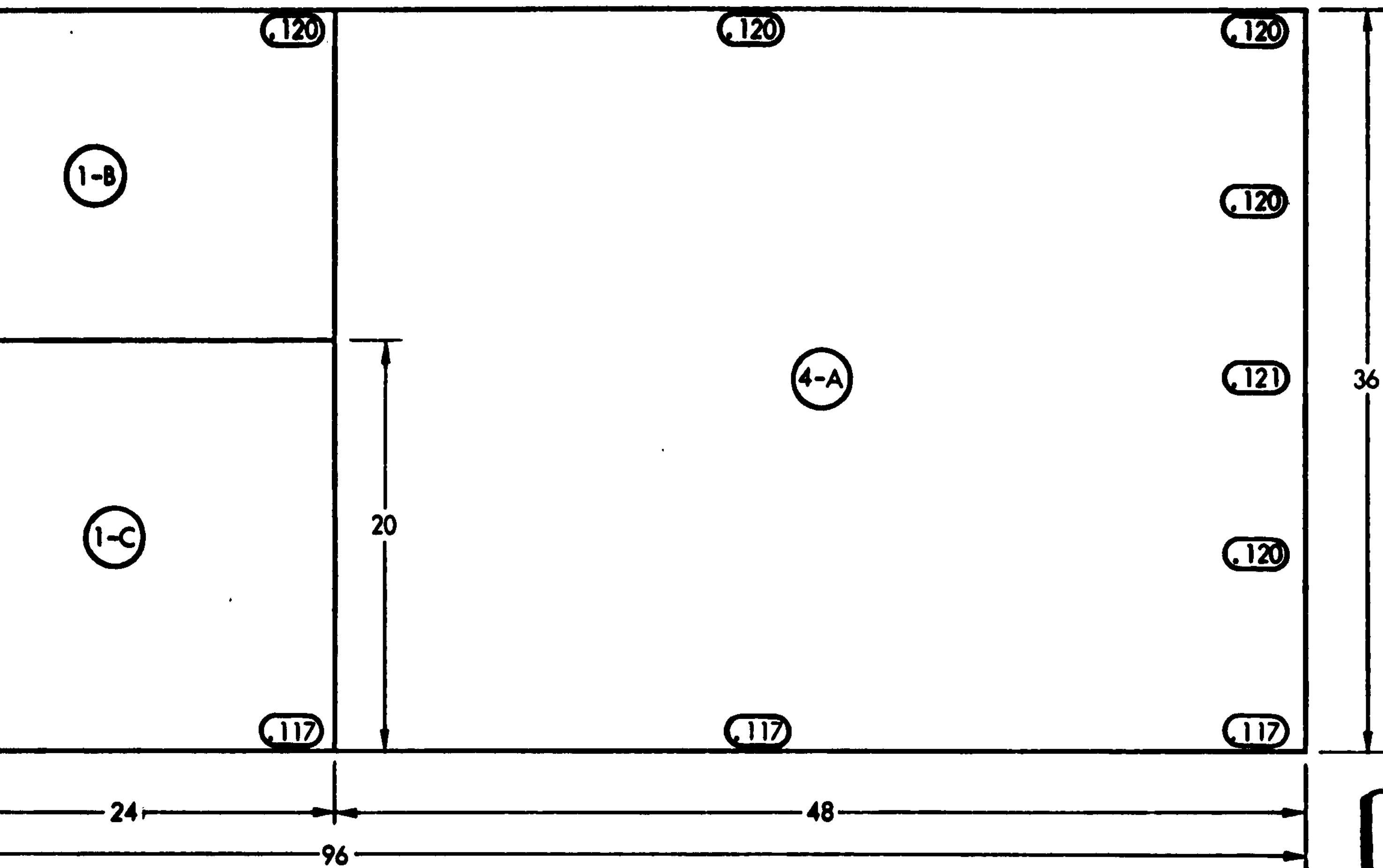
(4) FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

(5)

(6)

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE

INSPECTION AND LAYOUT PRINT FT-3-71



2

ST CODES

T WELD
T
A
ELD
DING PROCEDURE
CTS OF CHEMISTRY
P PROPERTIES

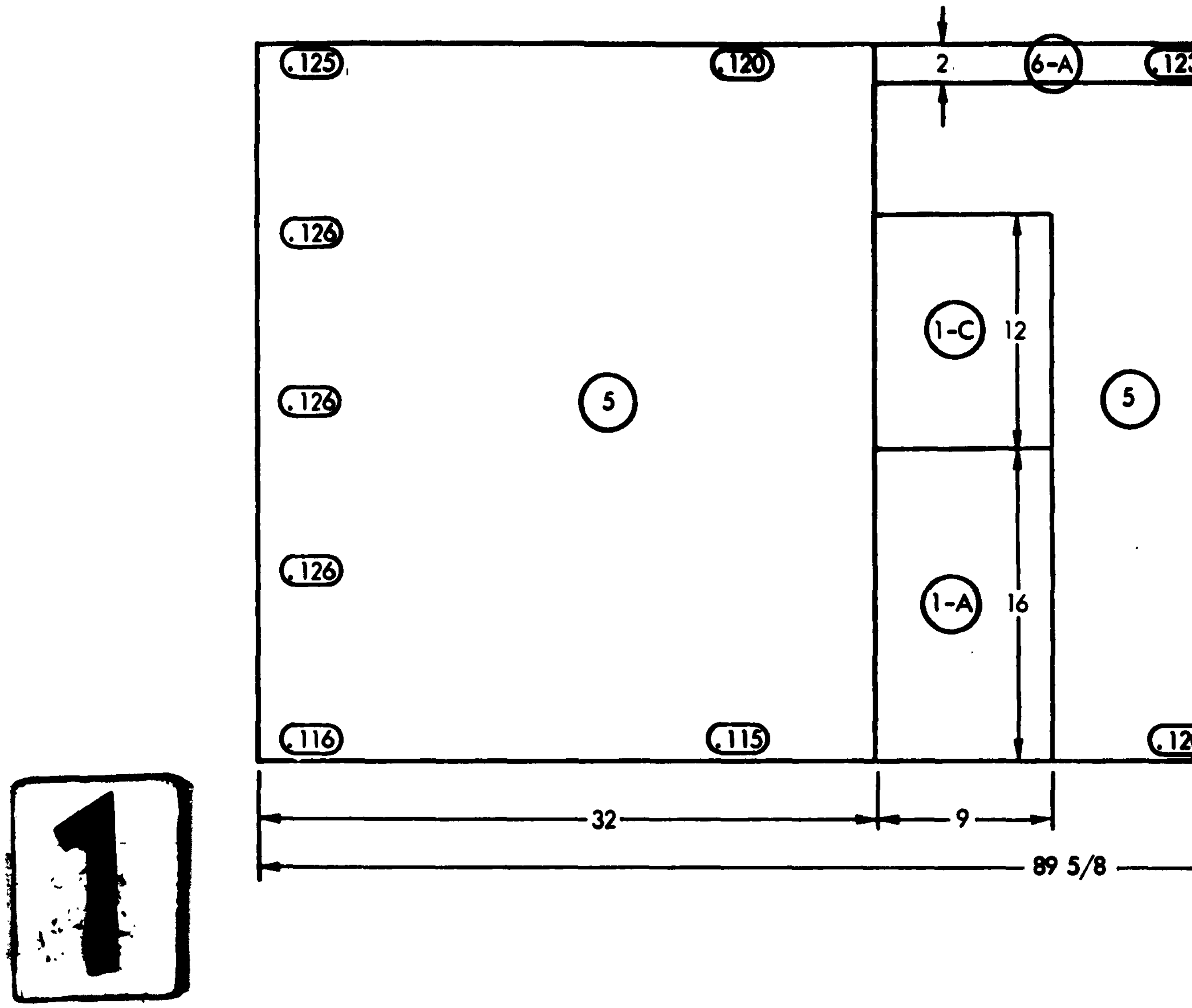
5 MACHINABILITY

6 FORMABILITY
- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	7Al. - 12Zr.
NOMINAL GAGE	.125
ACTUAL GAGE	.115 - .121
ACTUAL SIZE	36 x 96
HEAT NO.	V1788M
SHEET NO.	2
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOUT



TEST CODES

1 MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

2 SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

3 RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

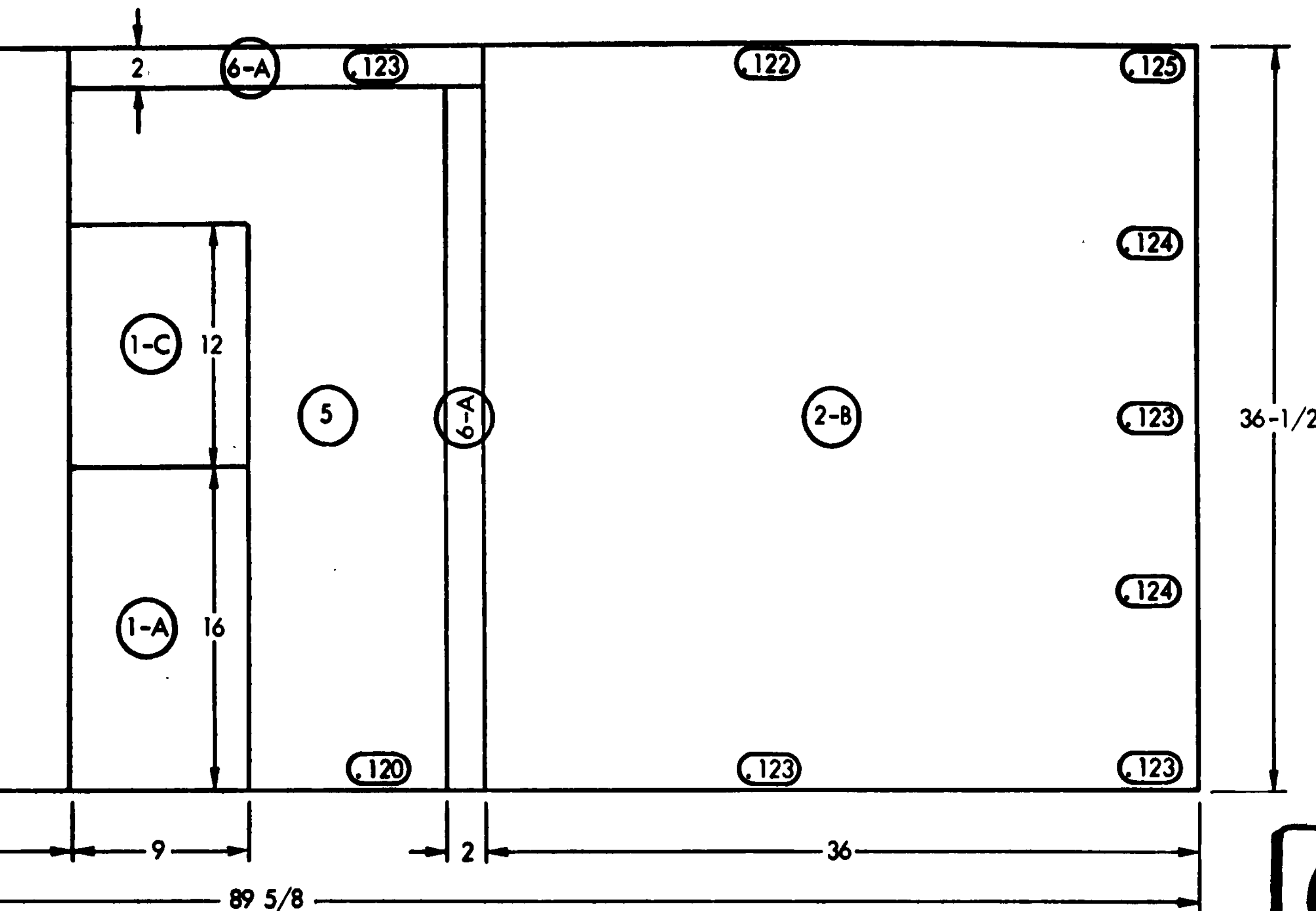
4 FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

5

6

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE

INSPECTION AND LAYOUT PRINT FT-3-72



2

T CODES

- WELD
- ELD
- DING PROCEDURE
- CTS OF CHEMISTRY
- P PROPERTIES

5 MACHINABILITY

6 FORMABILITY

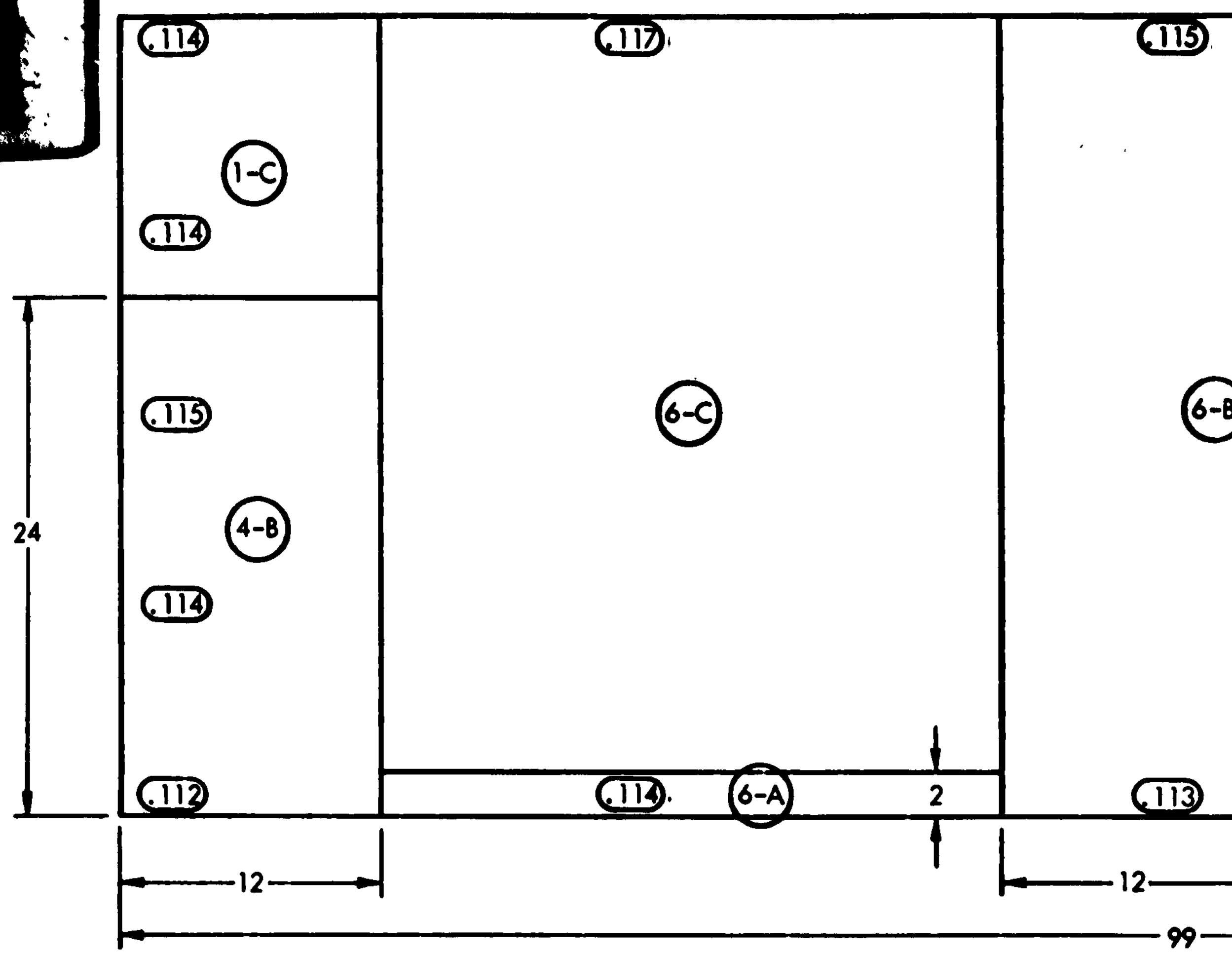
- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	7Al. - 12Zr.
NOMINAL GAGE	.125
ACTUAL GAGE	.115-.126
ACTUAL SIZE	36 1/2 x 89 5/8
HEAT NO.	32558
SHEET NO.	3179-5
FLATNESS	LESS THAN 1%
VENDOR	R.M.I.

1

INSPECTION AND LAYO



TEST CODES

1 MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

2 SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

3 RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

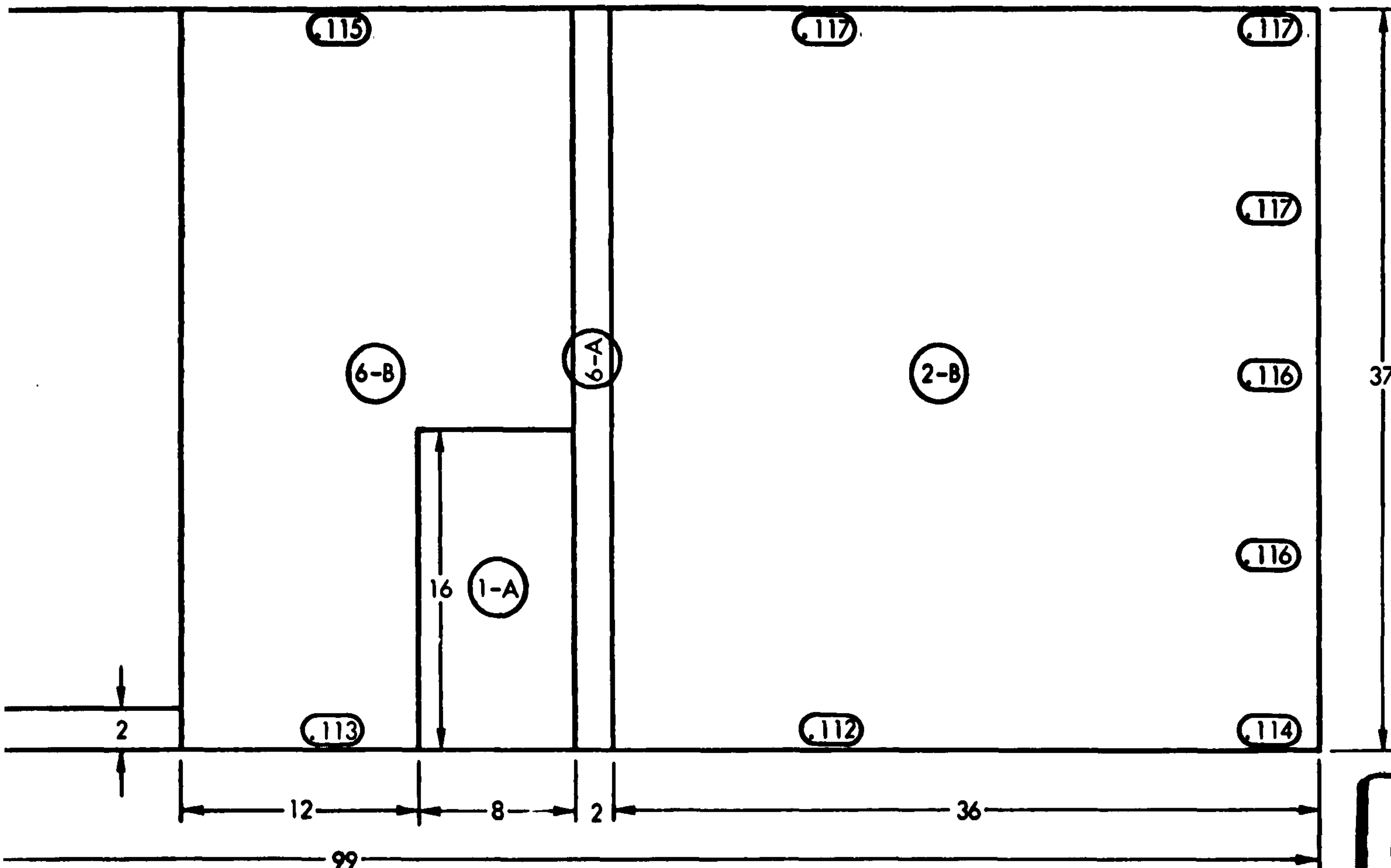
4 FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

5

6

THICKNESS MEASUREMENTS

SURFACE CONDITION: PRODUCTION ACCEPTABLE



2

:ST CODES

IT WELD

)T

.M

WELD

.DING PROCEDURE

:ECTS OF CHEMISTRY

:EP PROPERTIES

5 MACHINABILITY

6 FORMABILITY

6-A BEND AND SURFACE

6-B BEND AND JOGGLE

6-C BEND AND STRETCH

6-D HYDRO PRESS

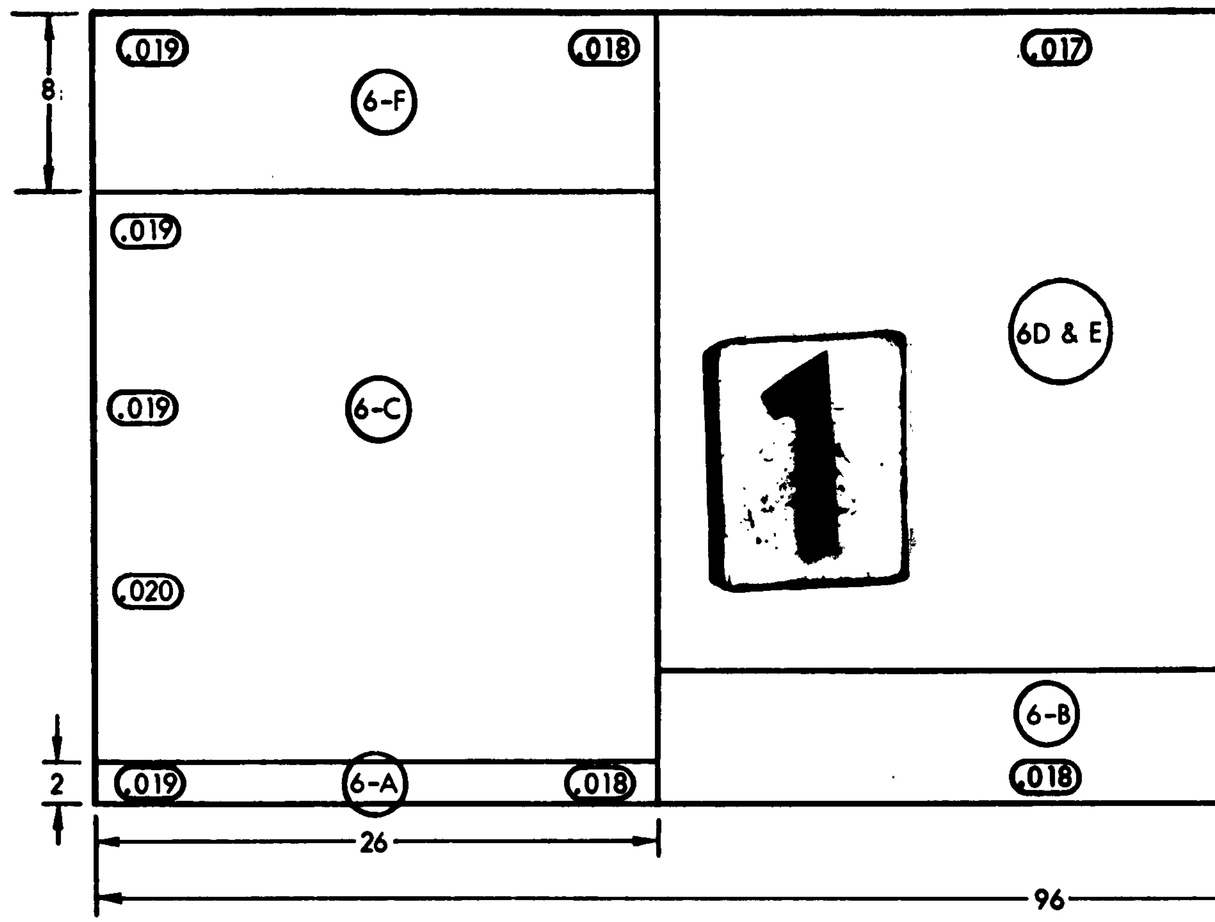
6-E HOT SIZE

6-F DIMPLE

MATERIAL DATA	
ALLOY	7Al. - 12Zr.
NOMINAL GAGE	.125
ACTUAL GAGE	.112-.117
ACTUAL SIZE	37 x 99
HEAT NO.	V19148
SHEET NO.	4
FLATNESS	LESS THAN 1%
VENDOR	TMCA

N: PRODUCTION ACCEPTABLE

INSPECTION AND LAYOU



TEST CODES

1 MECHANICAL PROPERTIES

1-A ROOM TEMPERATURE

1-B ROOM & ELEVATED TEMPERATURE

1-C CREEP PROPERTIES

2 SURFACE CONTAMINATION

2-A BEND AND TENSILE

2-B FATIGUE

2-C FABRICATION PRACTICES

3 RESISTANT WELD

3-A SPOT

3-B SEAM

4 FUSION WELD

4-A WELDING PROCEDURE

4-B AFFECTS OF CHEMISTRY

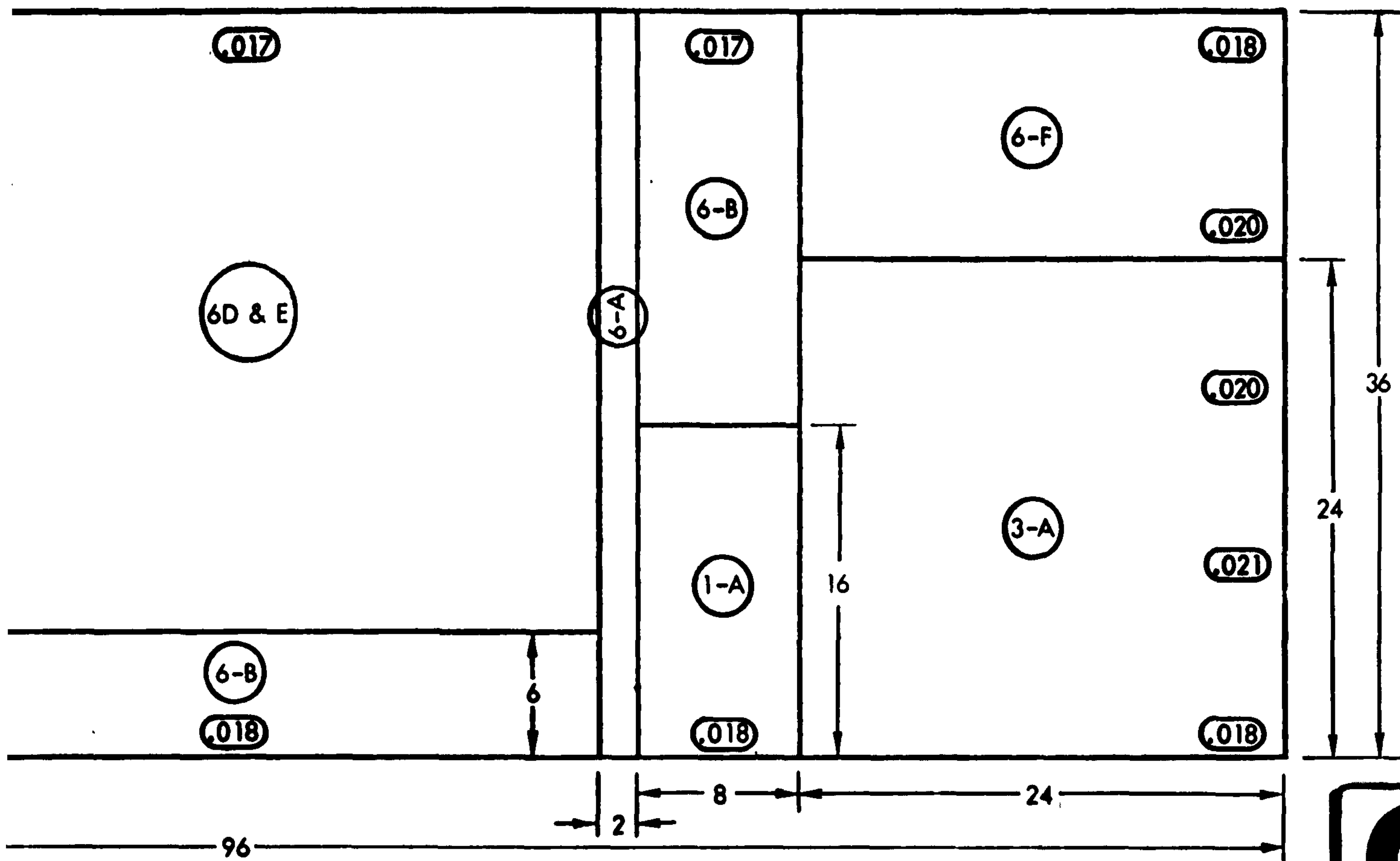
4-C CREEP PROPERTIES

5

6

THICKNESS MEASUREMENTS

SURFACE CONDITION: VERY SLIGHT GRIND MARKS



2

T CODES

WELD

\

ELD

ING PROCEDURE

CTS OF CHEMISTRY

P PROPERTIES

5 MACHINABILITY

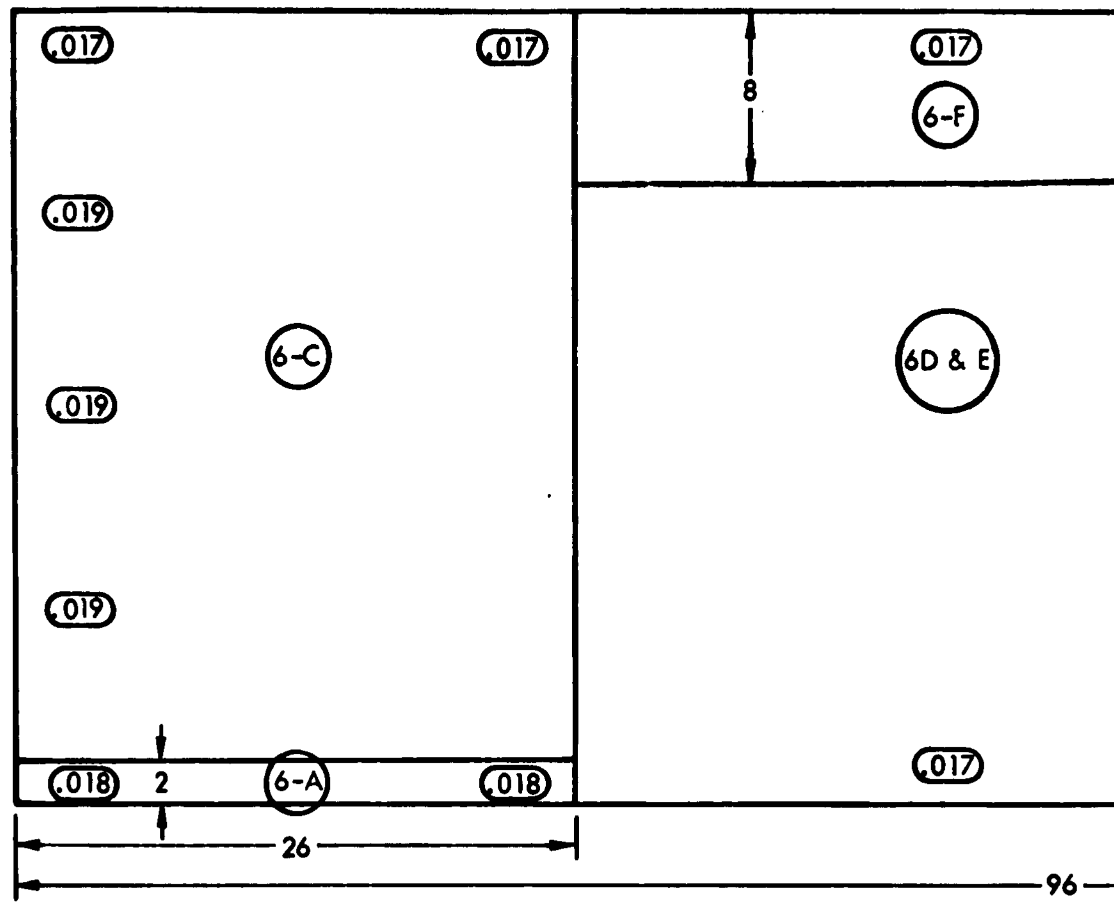
6 FORMABILITY

- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

: VERY SLIGHT GRIND MARKS ONE SURFACE

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5 Zr.
NOMINAL GAGE	.020
ACTUAL GAGE	.017 - .0
ACTUAL SIZE	36 x 96
HEAT NO.	V1813 M
SHEET NO.	1
FLATNESS	1%
VENDOR	TMCA

INSPECTION AND LAYOU



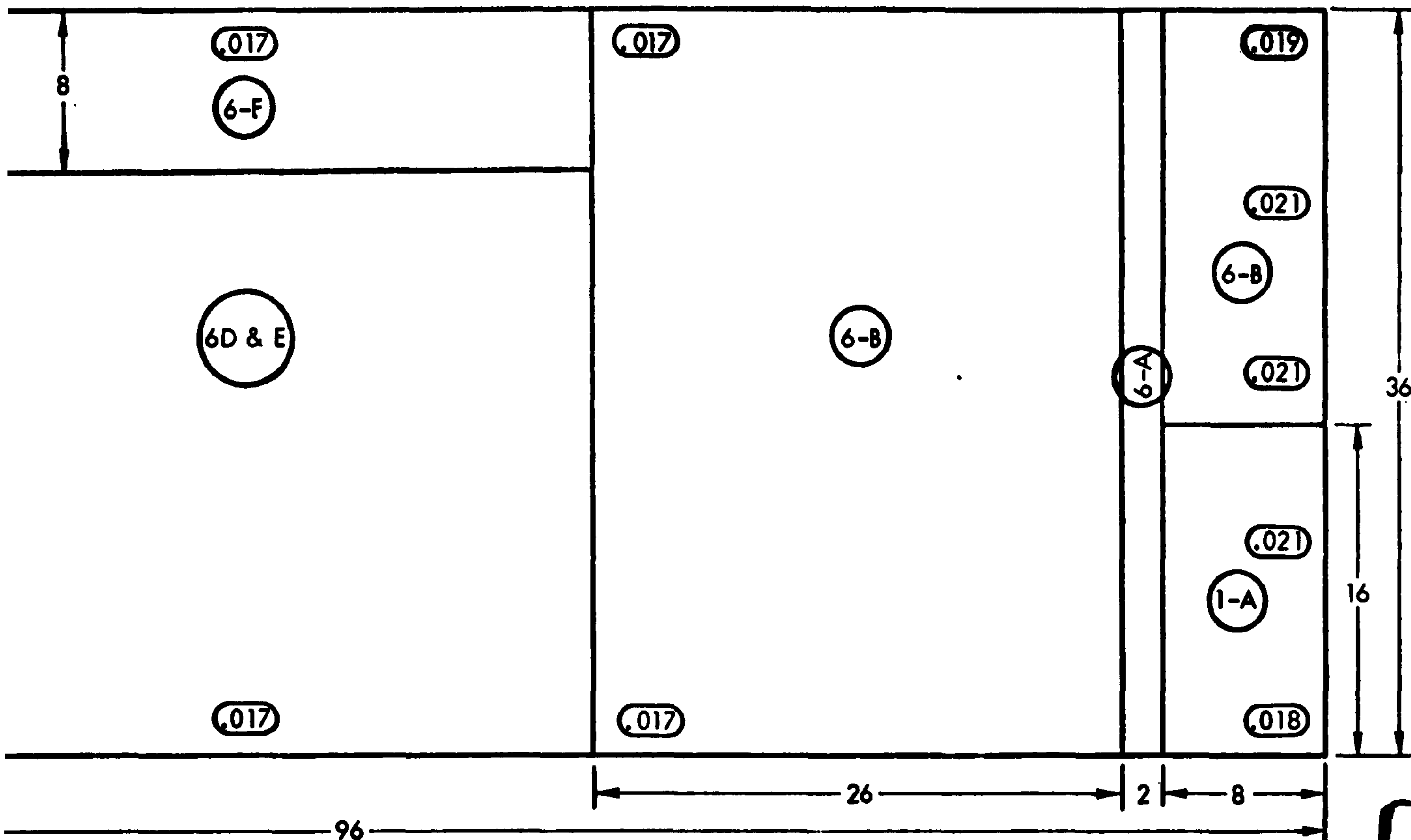
1

TEST CODES

1. MECHANICAL PROPERTIES
   - 1-A ROOM TEMPERATURE
   - 1-B ROOM & ELEVATED TEMPERATURE
   - 1-C CREEP PROPERTIES
2. SURFACE CONTAMINATION
   - 2-A BEND AND TENSILE
   - 2-B FATIGUE
   - 2-C FABRICATION PRACTICES
3. RESISTANT WELD
   - 3-A SPOT
   - 3-B SEAM
4. FUSION WELD
   - 4-A WELDING PROCEDURE
   - 4-B AFFECTS OF CHEMISTRY
   - 4-C CREEP PROPERTIES
5.
6.

THICKNESS MEASUREMENTS	SURFACE CONDITION: SLIGHT GRIND MARKS BOTH S

INSPECTION AND LAYOUT PRINT FT-1-74



2

ST CODES

' WELD
T
A
'ELD
DING PROCEDURE
CTS OF CHEMISTRY
P PROPERTIES

5 MACHINABILITY

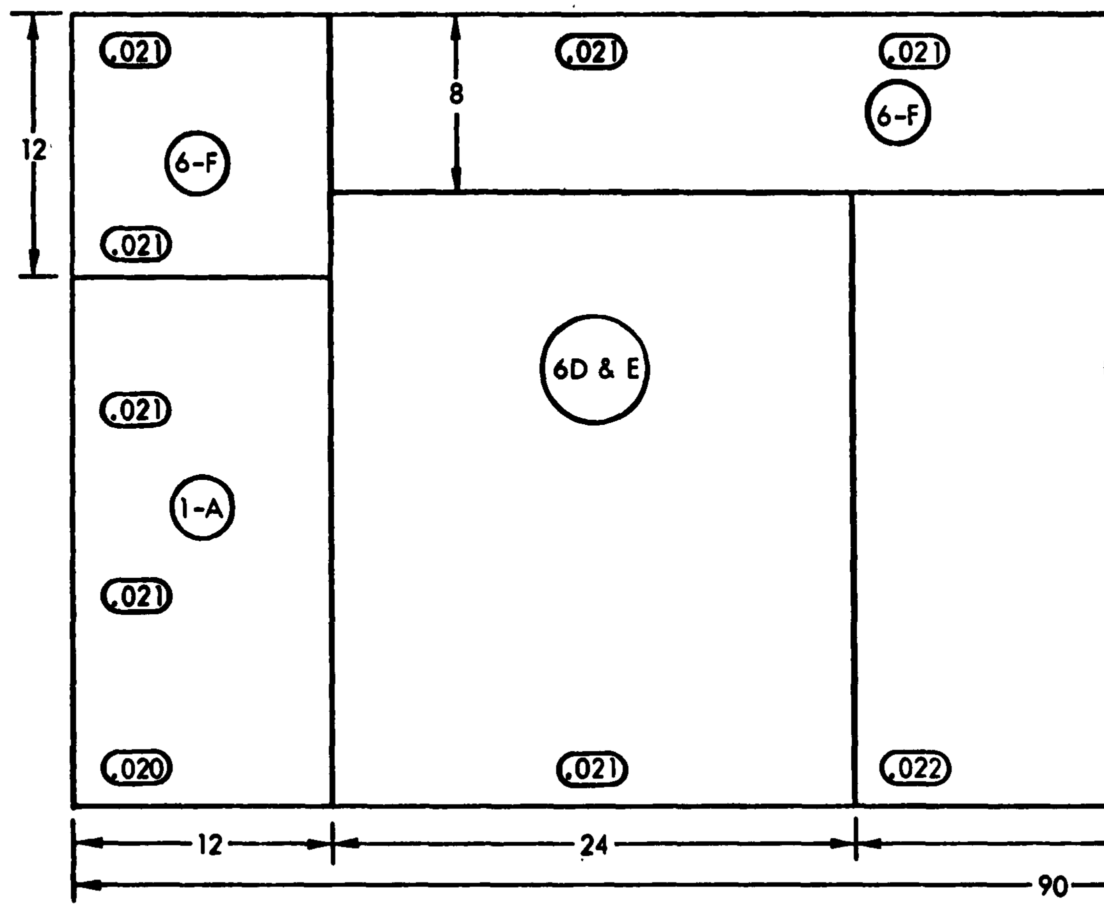
6 FORMABILITY

- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

: SLIGHT GRIND MARKS BOTH SIDES OF SHEET

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.020
ACTUAL GAGE	.017 - .021
ACTUAL SIZE	36 x 96
HEAT NO.	V1813M
SHEET NO.	6
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOUT



1

TEST CODES

1 MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

2 SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

3 RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

4 FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

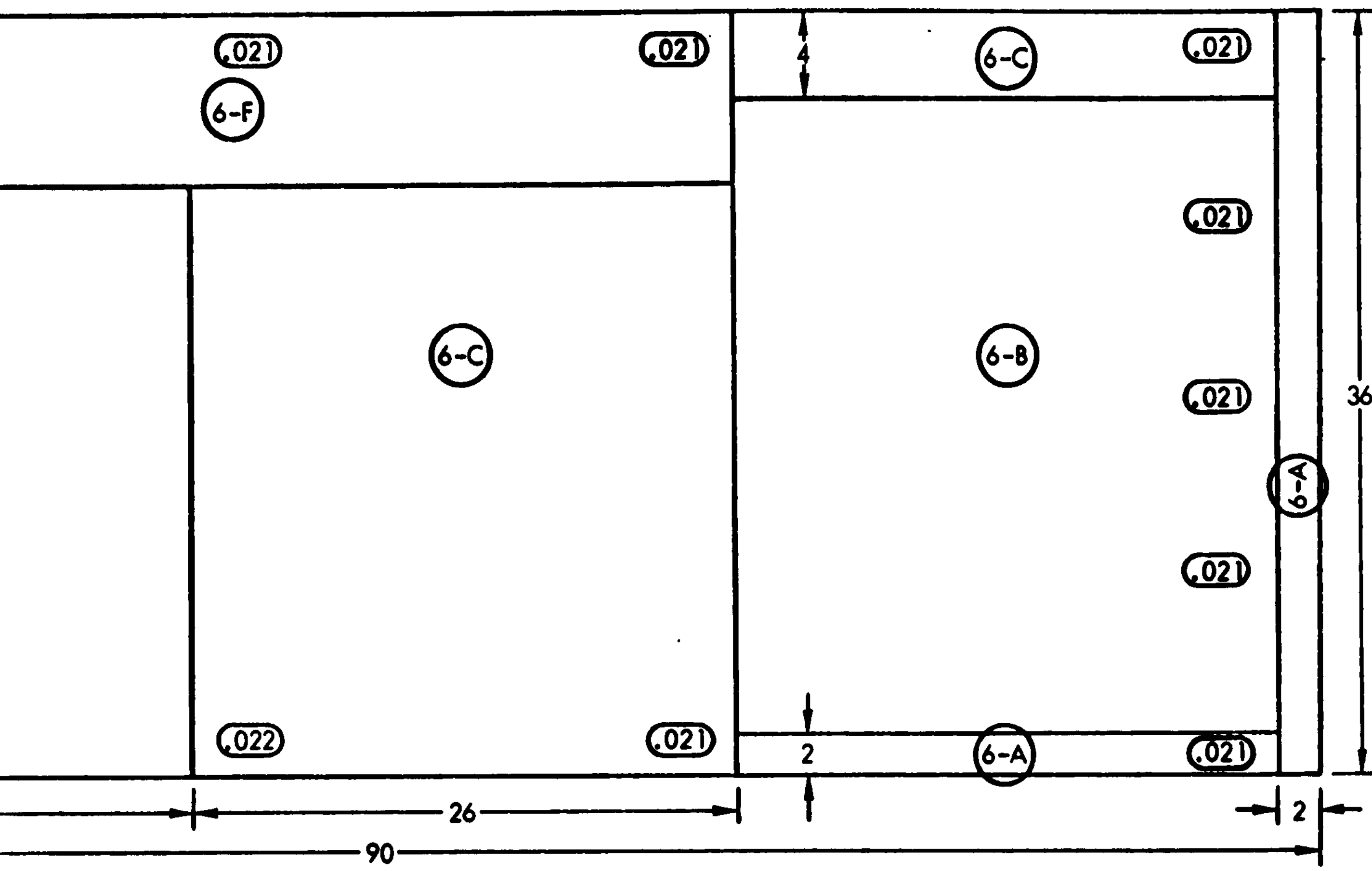
5

6

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE

INSPECTION AND LAYOUT PRINT FT-1-75

NA57H-527-16
Appendix I



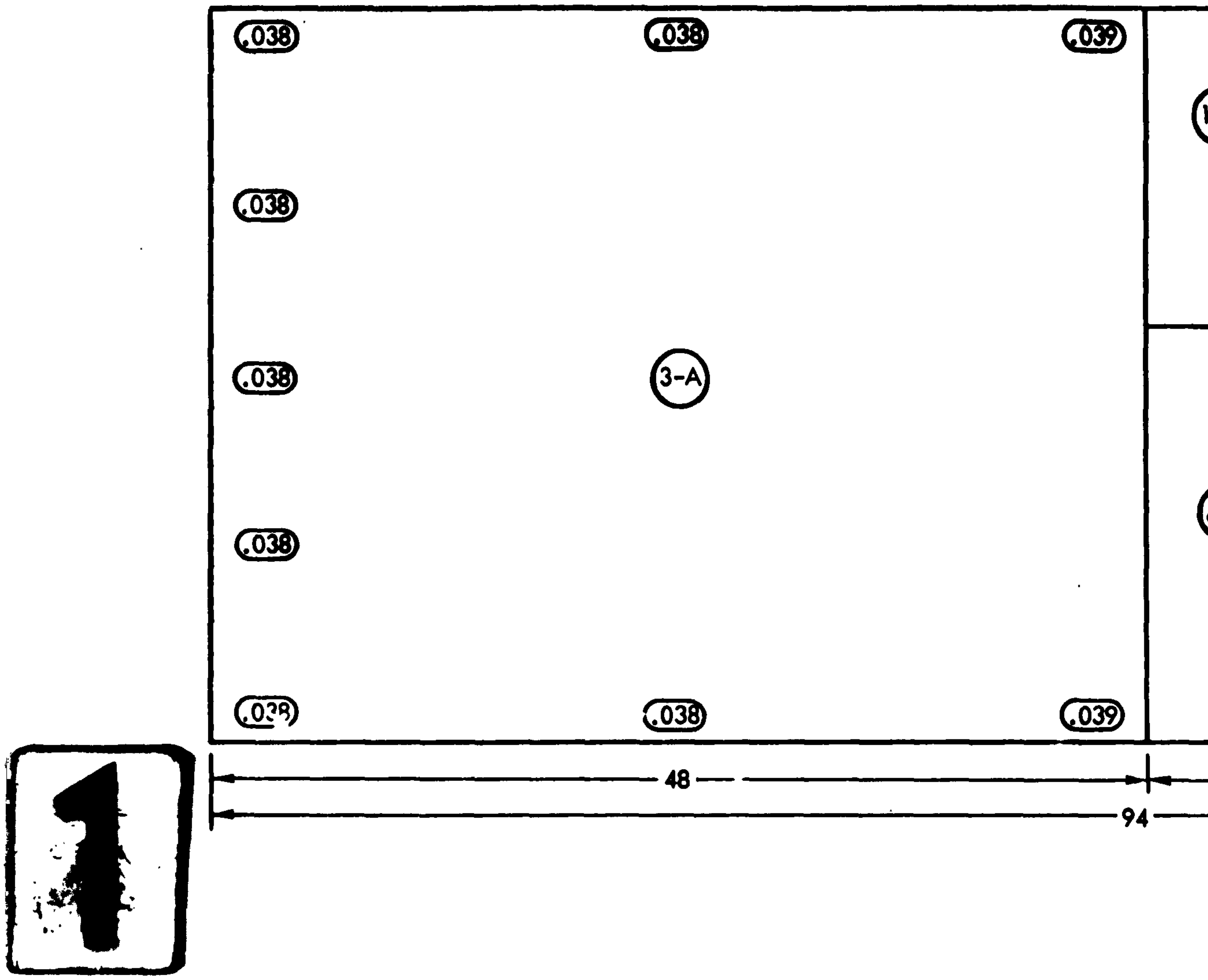
2

ST CODES		
T WELD	5	MACHINABILITY
OT	6	FORMABILITY
M	6-A	BEND AND SURFACE
	6-B	BEND AND JOGGLE
VELD	6-C	BEND AND STRETCH
DING PROCEDURE	6-D	HYDRO PRESS
ECTS OF CHEMISTRY	6-E	HOT SIZE
EP PROPERTIES	6-F	DIMPLE

N: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.020
ACTUAL GAGE	.020 - .022
ACTUAL SIZE	36 x 90
HEAT NO.	V1785 M
SHEET NO.	1
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOUT



TEST CODES

1 MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

2 SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

3 RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

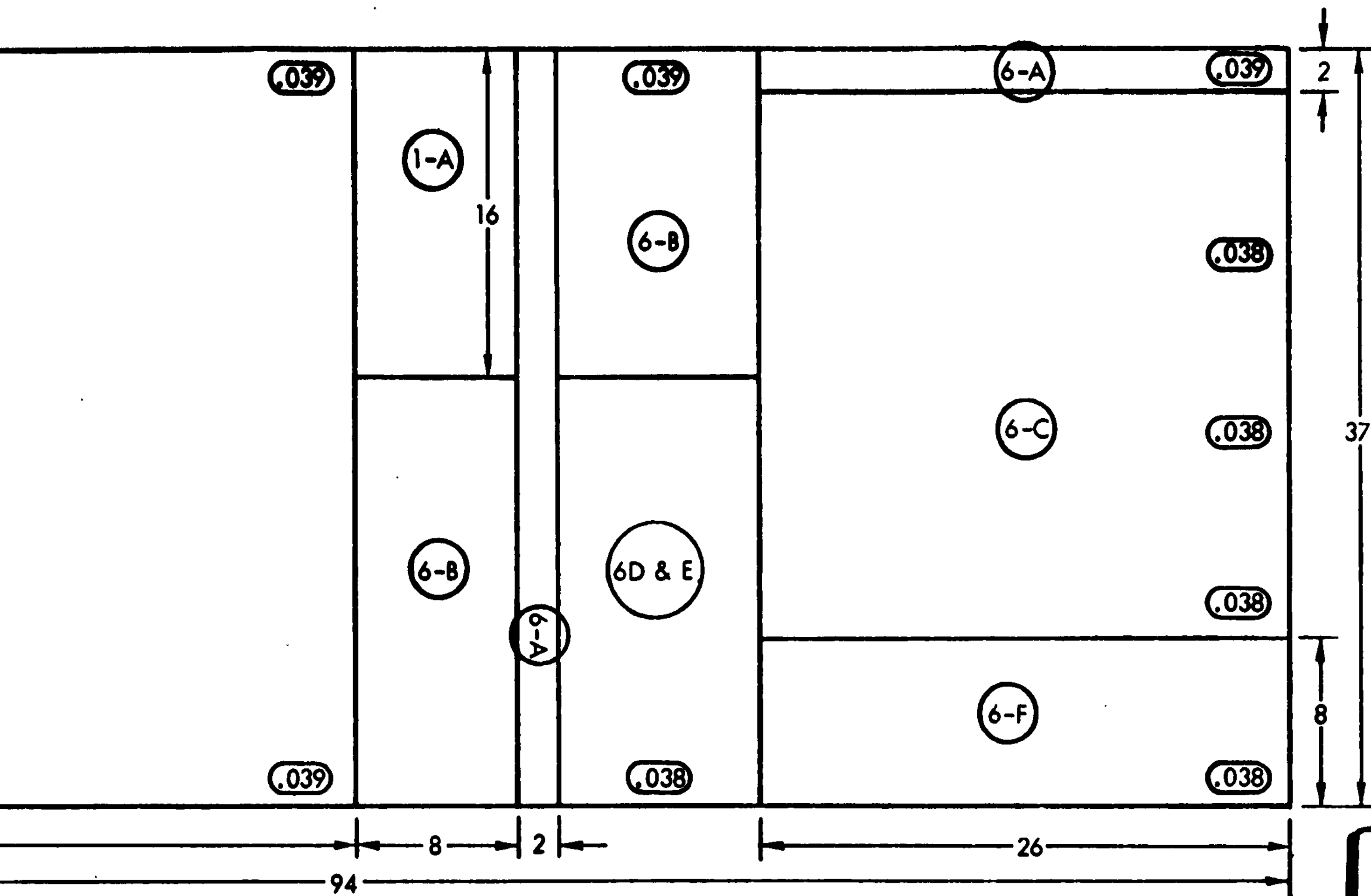
4 FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

5

6

THICKNESS MEASUREMENTS	SURFACE CONDITION: LACK OF CLEANING OR COR FINE GRIND MARKS BOTH SID

INSPECTION AND LAYOUT PRINT FT-1-76



2

ST CODES

T WELD
T
M
VELD
DING PROCEDURE
ECTS OF CHEMISTRY
EP PROPERTIES

5 MACHINABILITY

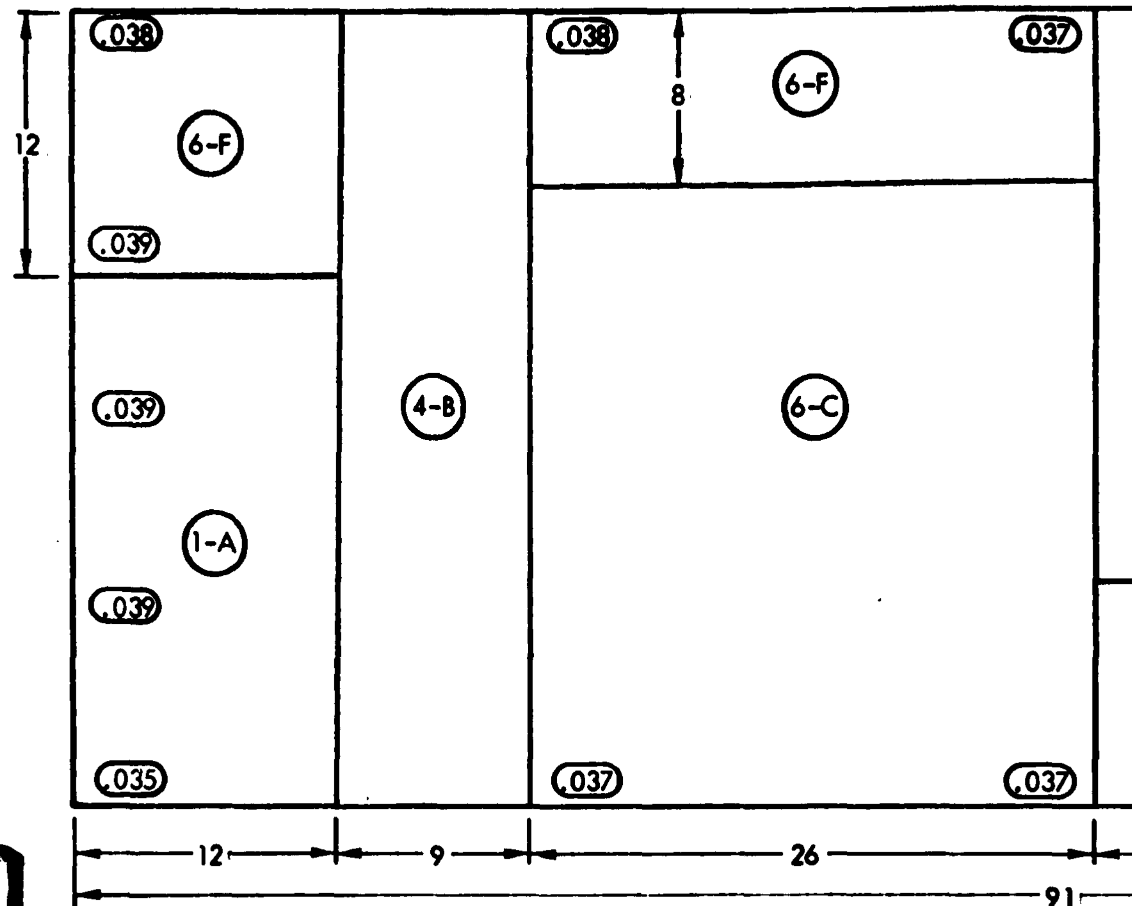
6 FORMABILITY

- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

: LACK OF CLEANING OR CORROSION AND FINE GRIND MARKS BOTH SIDES

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.040
ACTUAL GAGE	.038 - .039
ACTUAL SIZE	37 x 94
HEAT NO.	V1813 M
SHEET NO.	5
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOUT



1

TEST CODES

1 MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

2 SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

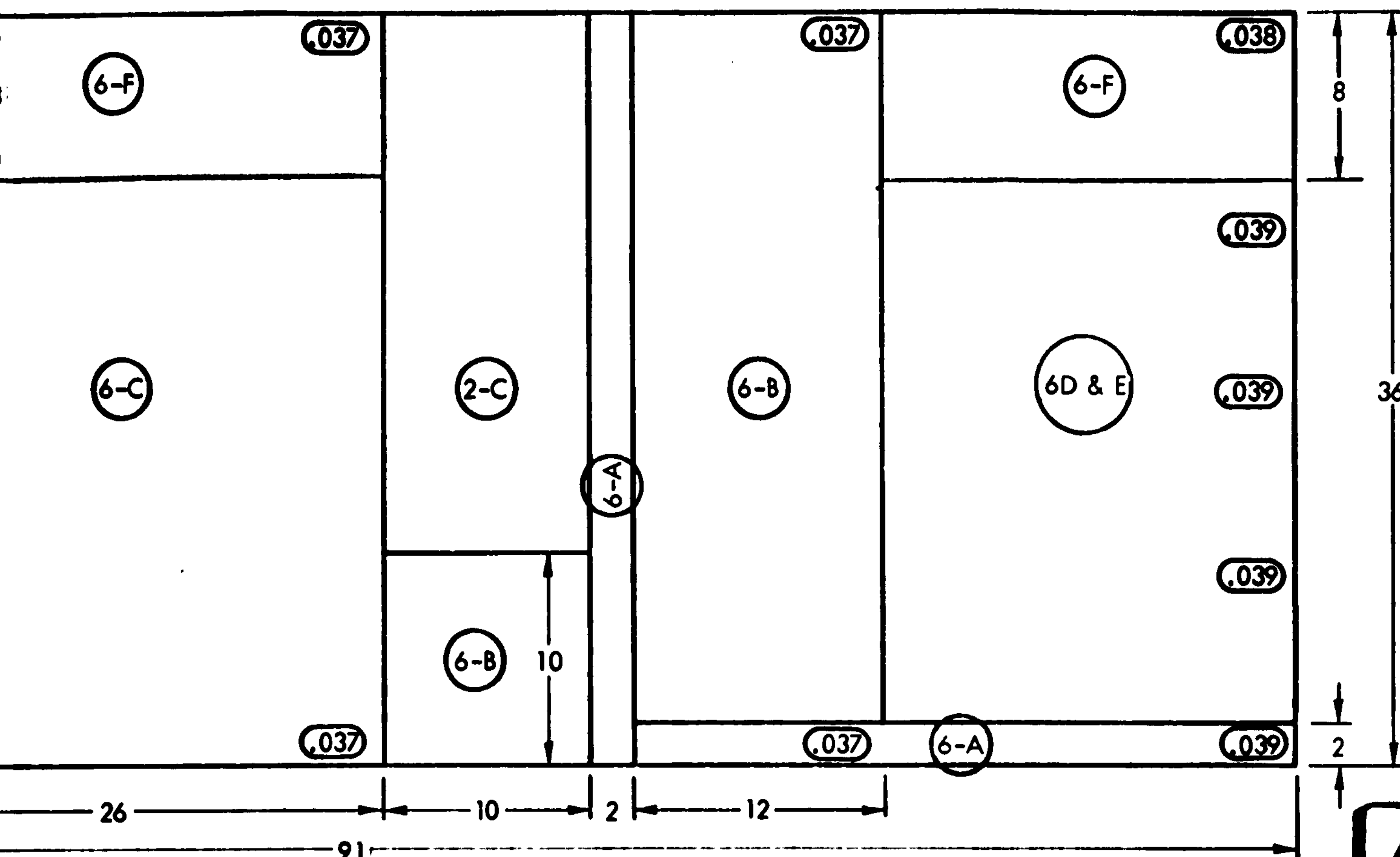
3 RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

4 FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

5

6

⬭ THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE



2

ST CODES

T WELD

OT

M

VELD

LDING PROCEDURE

ECTS OF CHEMISTRY

EP PROPERTIES

5 MACHINABILITY

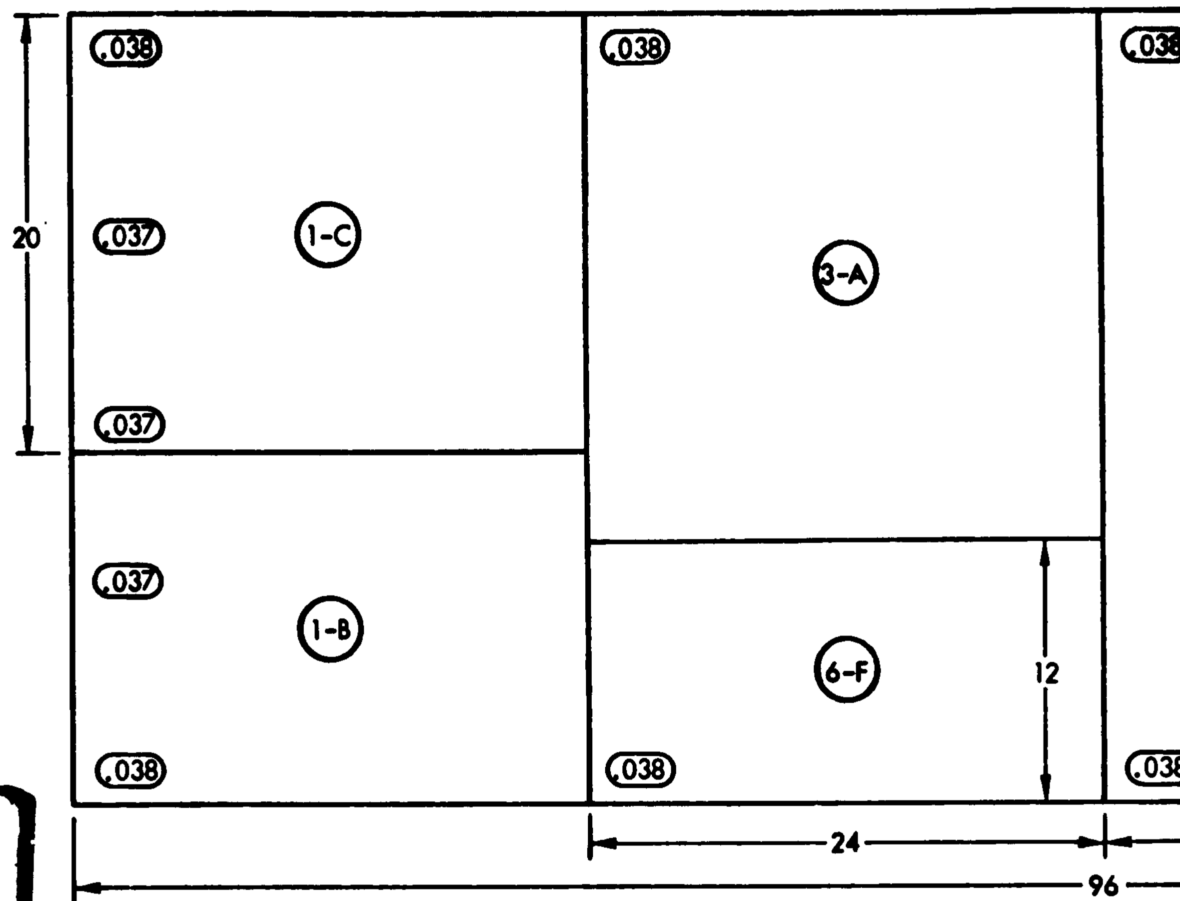
6 FORMABILITY

- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

N: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.040
ACTUAL GAGE	.035 - .039
ACTUAL SIZE	36 x 91
HEAT NO.	V1785 M
SHEET NO.	8
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOUT

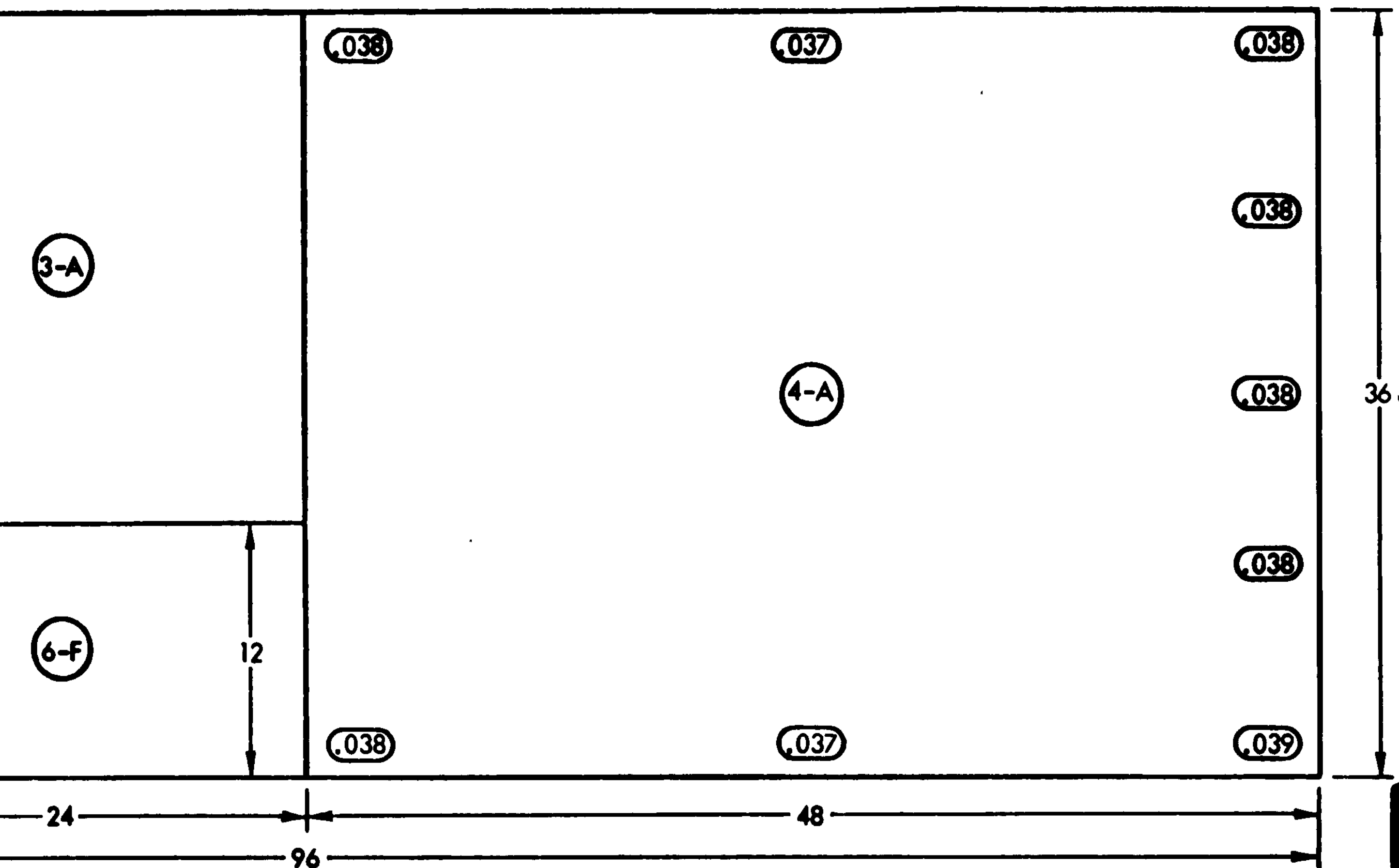


1

TEST CODES

1. MECHANICAL PROPERTIES
   - 1-A ROOM TEMPERATURE
   - 1-B ROOM & ELEVATED TEMPERATURE
   - 1-C CREEP PROPERTIES
2. SURFACE CONTAMINATION
   - 2-A BEND AND TENSILE
   - 2-B FATIGUE
   - 2-C FABRICATION PRACTICES
3. RESISTANT WELD
   - 3-A SPOT
   - 3-B SEAM
4. FUSION WELD
   - 4-A WELDING PROCEDURE
   - 4-B AFFECTS OF CHEMISTRY
   - 4-C CREEP PROPERTIES
5. M
6. F

THICKNESS MEASUREMENTS	SURFACE CONDITION:	DIFFERENTIAL ETCH THREE (3) F (BELIEVED DUE TO CONTACT W



2

CODES

ELD

)

G PROCEDURE

OF CHEMISTRY

ROPERTIES

5 MACHINABILITY

6 FORMABILITY

6-A BEND AND SURFACE

6-B BEND AND JOGGLE

6-C BEND AND STRETCH

6-D HYDRO PRESS

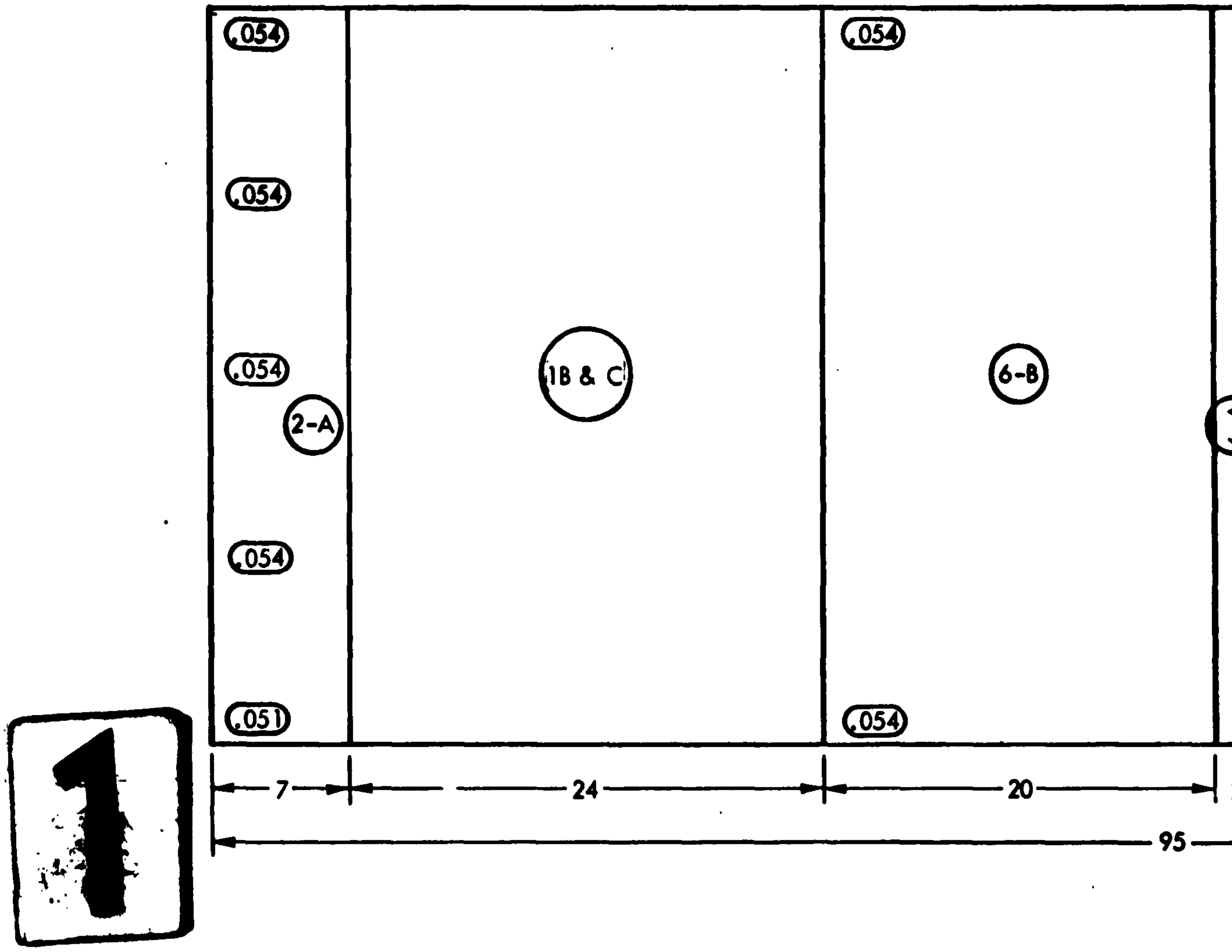
6-E HOT SIZE

6-F DIMPLE

DIFFERENTIAL ETCH THREE (3) PLACES.
(BELIEVED DUE TO CONTACT WITH ETCH RACK.)

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.040
ACTUAL GAGE	.037 - .039
ACTUAL SIZE	36 x 96
HEAT NO.	V1813 M
SHEET NO.	9
FLATNESS	LESS THAN 1%
VENDOR	TMCA
	PAGE 36

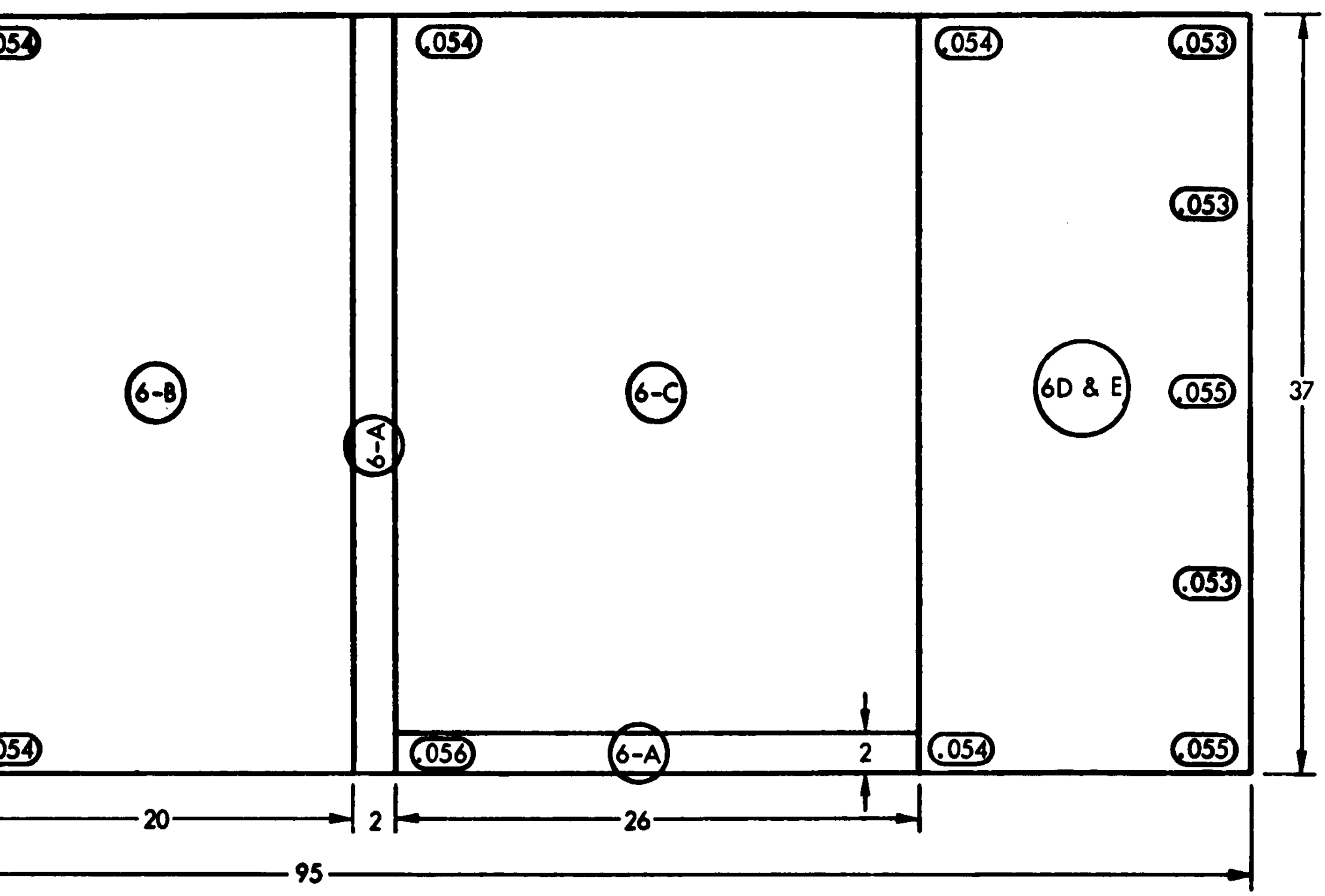
INSPECTION AND LAYOU



TEST CODES

1. MECHANICAL PROPERTIES
   - 1-A ROOM TEMPERATURE
   - 1-B ROOM & ELEVATED TEMPERATURE
   - 1-C CREEP PROPERTIES
2. SURFACE CONTAMINATION
   - 2-A BEND AND TENSILE
   - 2-B FATIGUE
   - 2-C FABRICATION PRACTICES
3. RESISTANT WELD
   - 3-A SPOT
   - 3-B SEAM
4. FUSION WELD
   - 4-A WELDING PROCEDURE
   - 4-B AFFECTS OF CHEMISTRY
   - 4-C CREEP PROPERTIES
5.
6.

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE



2

CODES

VELD

LD

NG PROCEDURE

TS OF CHEMISTRY

PROPERTIES

5 MACHINABILITY

6 FORMABILITY

6-A BEND AND SURFACE

6-B BEND AND JOGGLE

6-C BEND AND STRETCH

6-D HYDRO PRESS

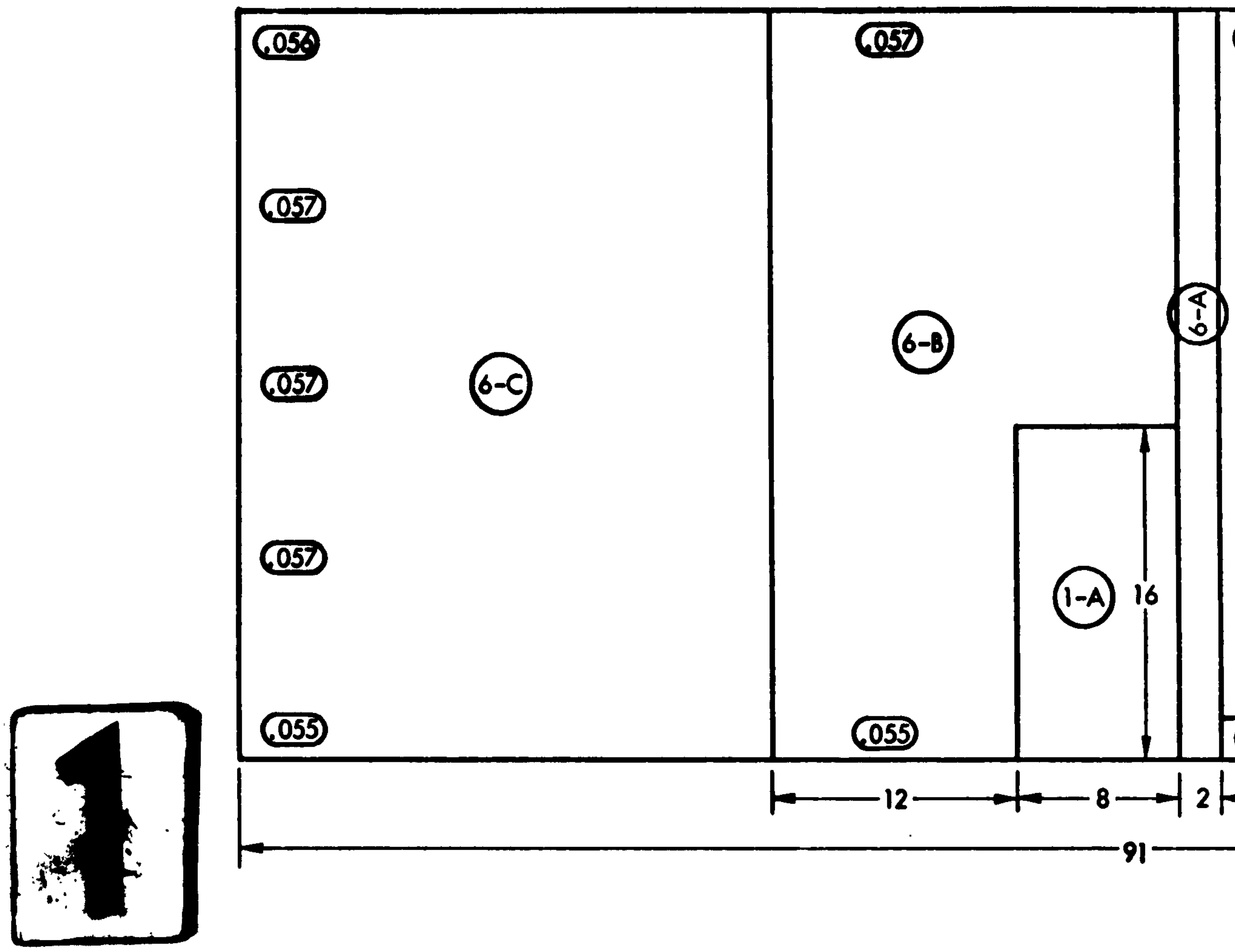
6-E HOT SIZE

6-F DIMPLE

PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.062
ACTUAL GAGE	.051 - .056
ACTUAL SIZE	37 x 95
HEAT NO.	V1784 M
SHEET NO.	2
FLATNESS	1%
VENDOR	TMCA

INSPECTION AND LAYOU

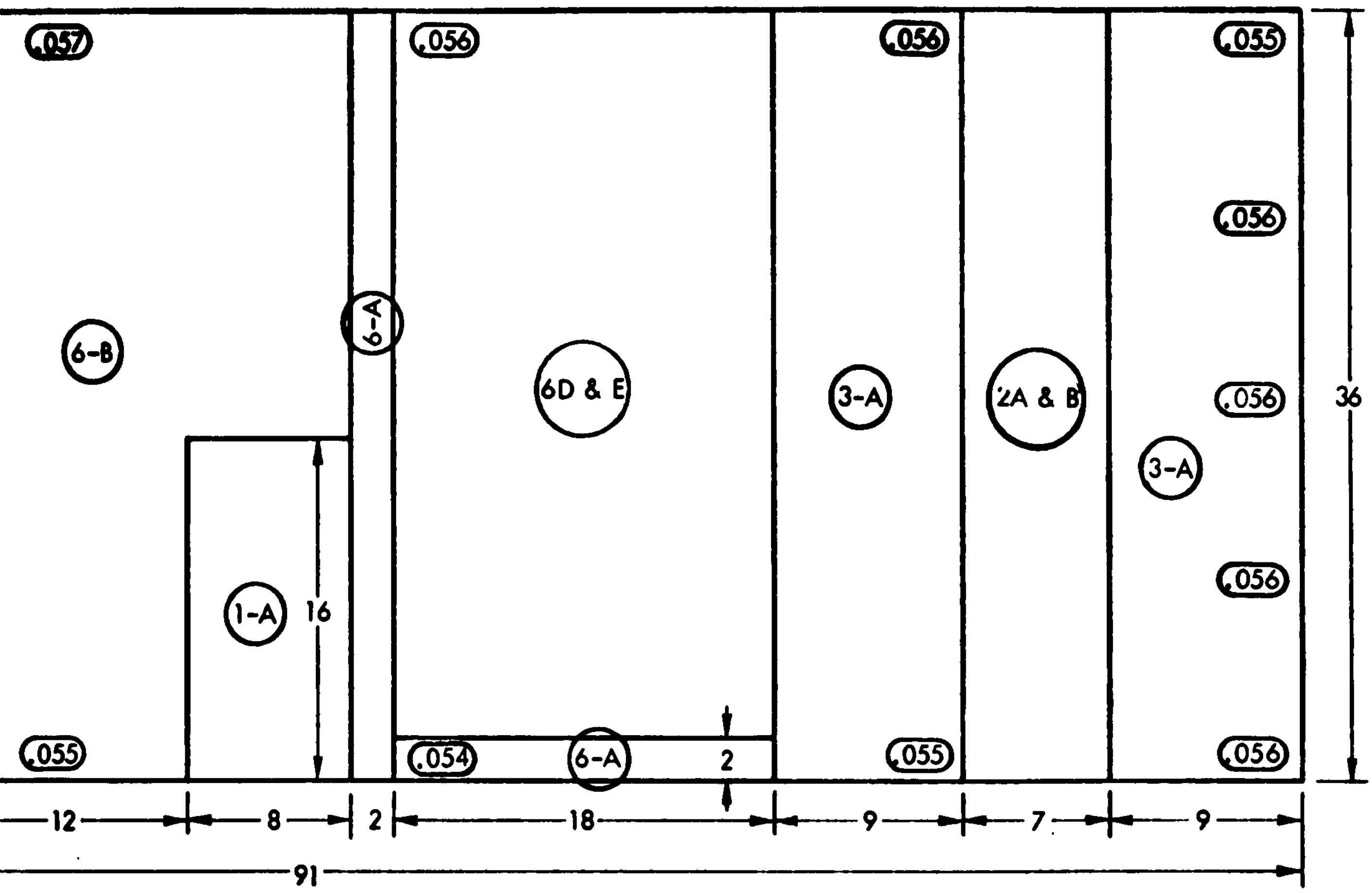


TEST CODES

1. MECHANICAL PROPERTIES
   - 1-A ROOM TEMPERATURE
   - 1-B ROOM & ELEVATED TEMPERATURE
   - 1-C CREEP PROPERTIES
2. SURFACE CONTAMINATION
   - 2-A BEND AND TENSILE
   - 2-B FATIGUE
   - 2-C FABRICATION PRACTICES
3. RESISTANT WELD
   - 3-A SPOT
   - 3-B SEAM
4. FUSION WELD
   - 4-A WELDING PROCEDURE
   - 4-B AFFECTS OF CHEMISTRY
   - 4-C CREEP PROPERTIES
5.
6.

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE

INSPECTION AND LAYOUT PRINT FT-1-80



2

ST CODES

T WELD
T
M
VELD
DING PROCEDURE
ECTS OF CHEMISTRY
EP PROPERTIES

5 MACHINABILITY

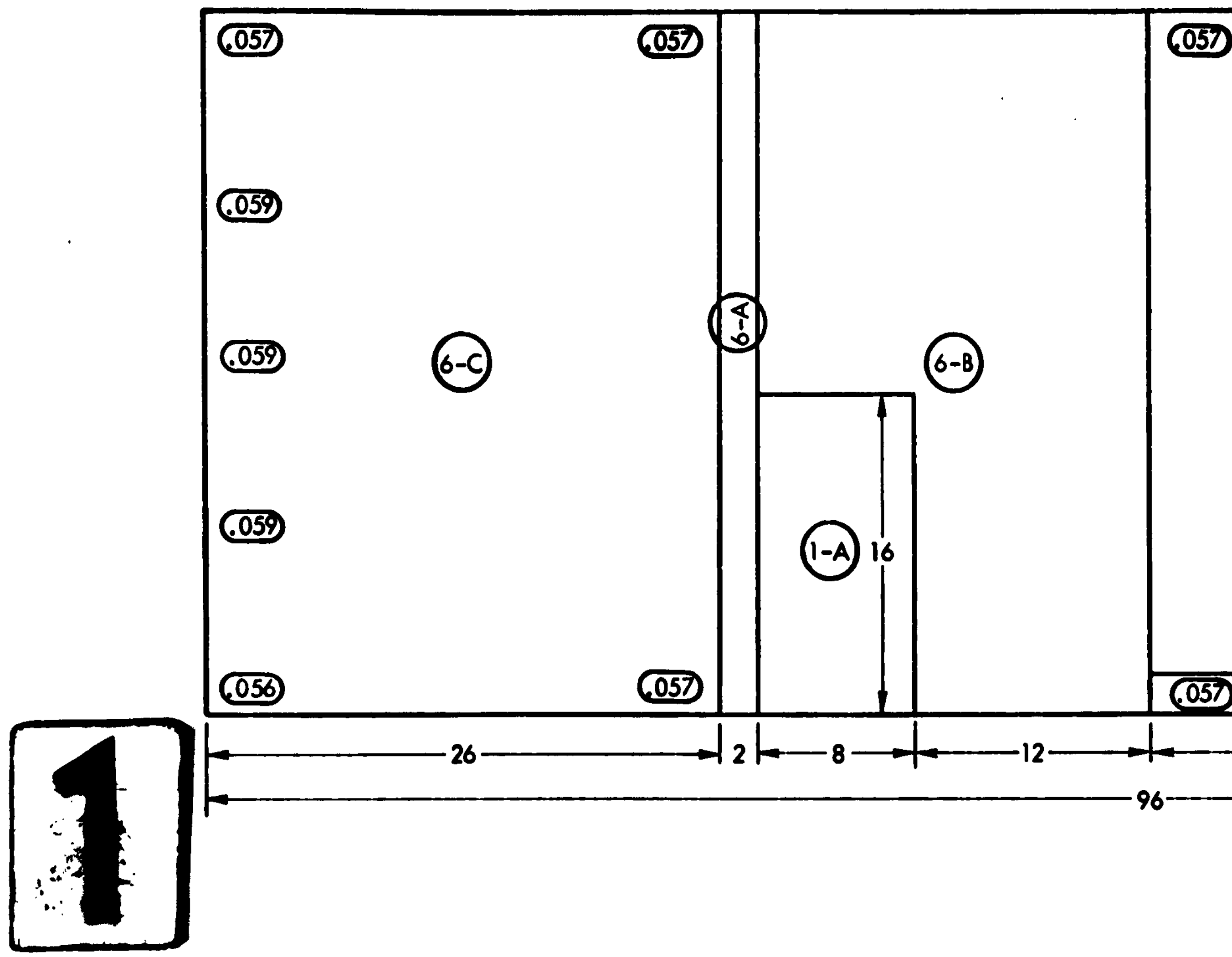
6 FORMABILITY

6-A BEND AND SURFACE
6-B BEND AND JOGGLE
6-C BEND AND STRETCH
6-D HYDRO PRESS
6-E HOT SIZE
6-F DIMPLE

: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.062
ACTUAL GAGE	.054 - .057
ACTUAL SIZE	36 x 91
HEAT NO.	V1813B
SHEET NO.	4
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOU



TEST CODES

① MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

② SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

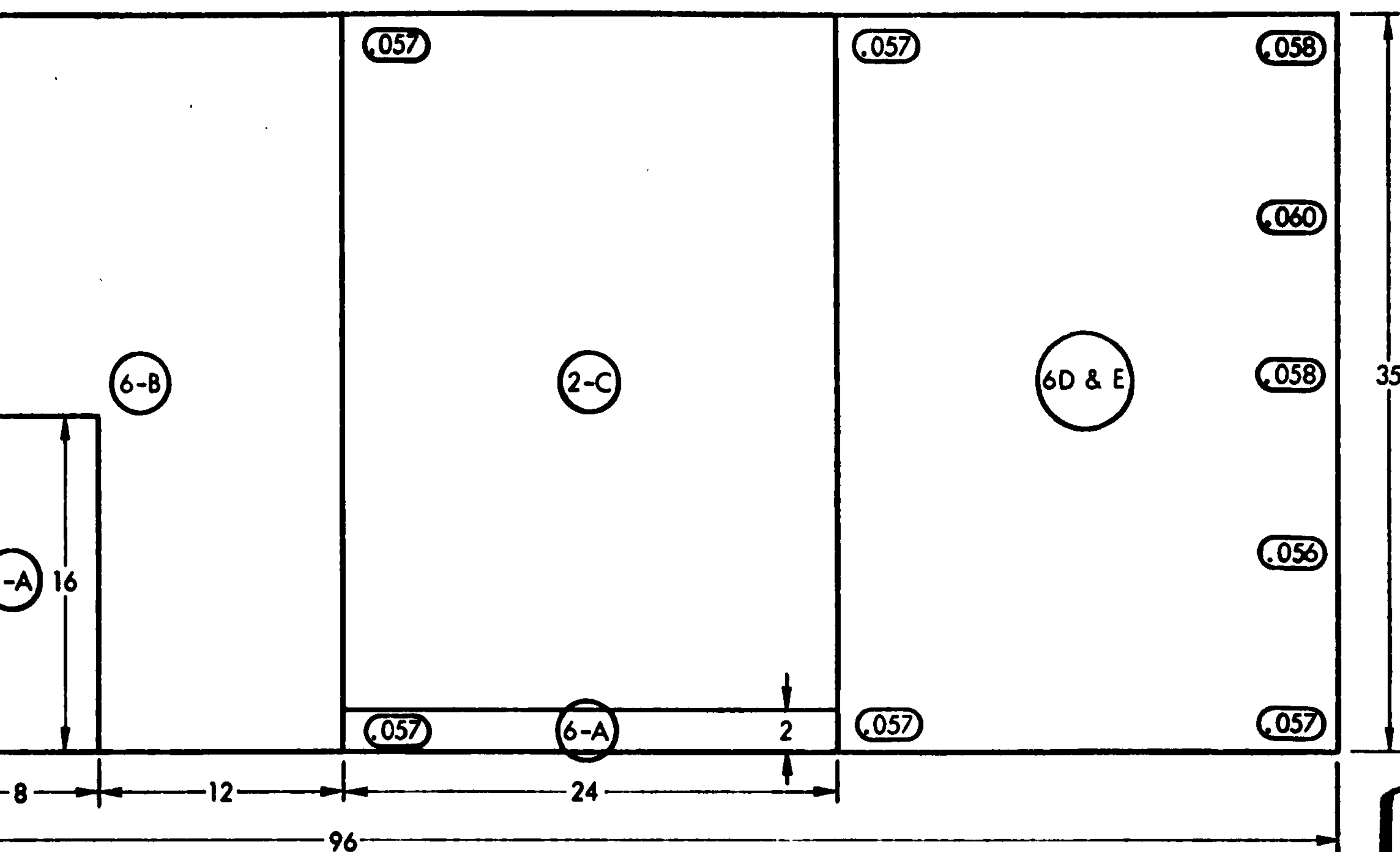
③ RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

④ FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

⑤

⑥

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE



2

TEST CODES

NT WELD
OT
AM
WELD
ELDING PROCEDURE
FECTS OF CHEMISTRY
EEP PROPERTIES

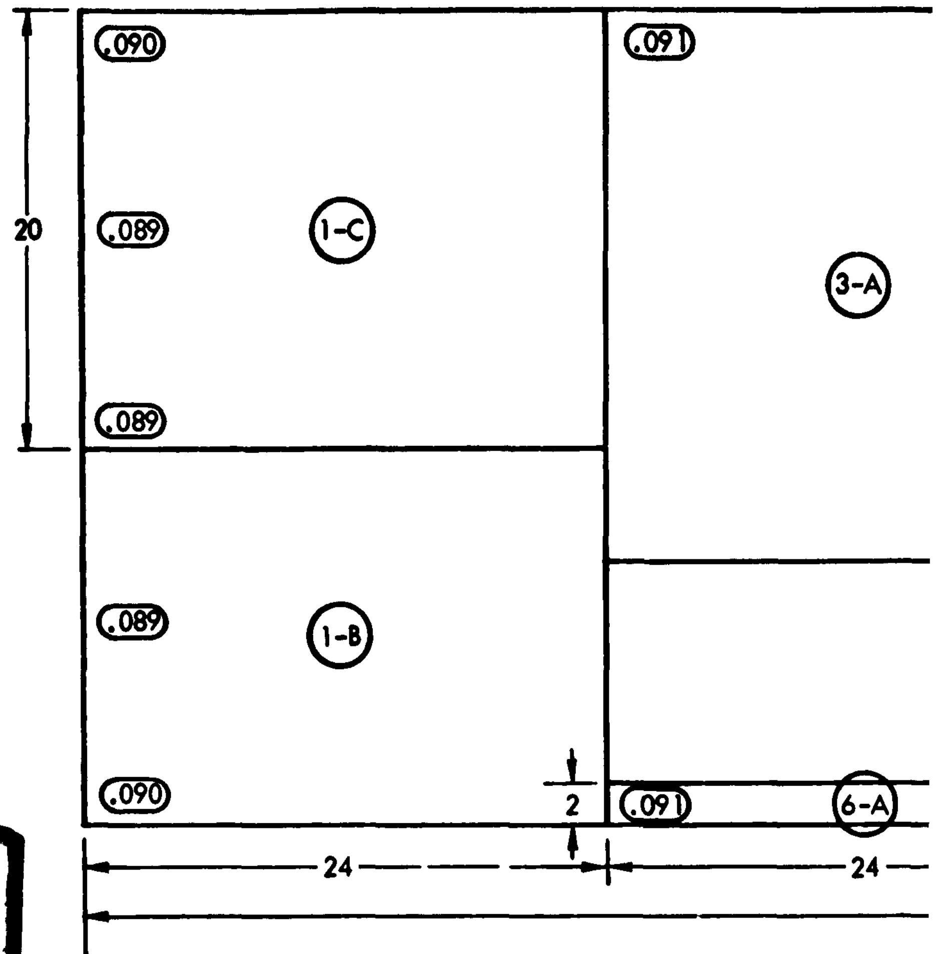
5 MACHINABILITY

6 FORMABILITY
- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

ON: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.062
ACTUAL GAGE	.056 - .060
ACTUAL SIZE	35 x 96
HEAT NO.	V1784 M
SHEET NO.	1
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECT!ON



1

TEST CODES

1 MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

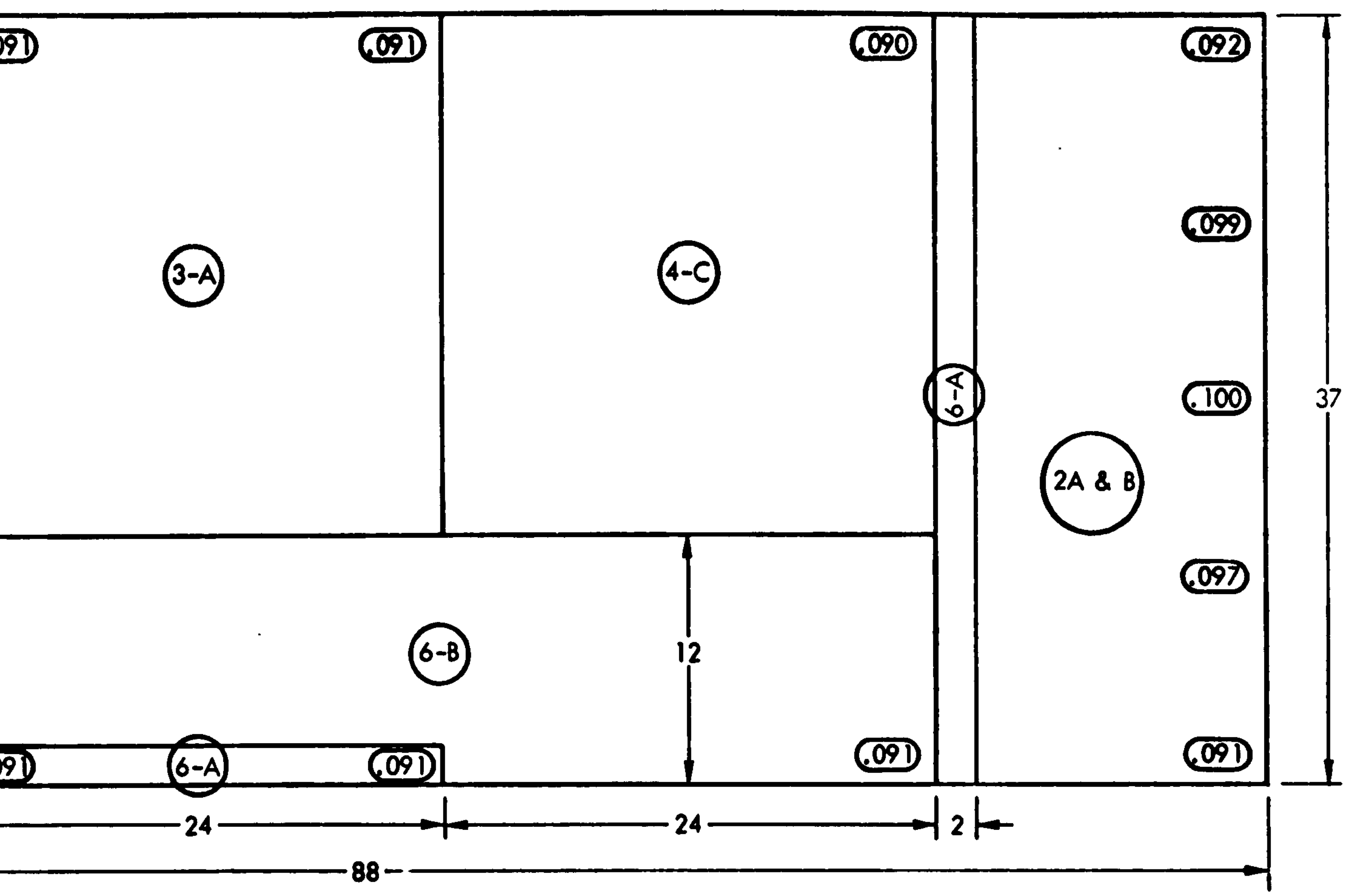
2 SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

3 RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

4 FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

THICKNESS MEASUREMENTS	SURFACE CONDITION: WHITE CORROSIVE THREE (3) PLACES.

INSPECTION AND LAYOUT PRINT FT-2-82



2

EST CODES

IT WELD
OT
AM
WELD
LDING PROCEDURE
FECTS OF CHEMISTRY
EEP PROPERTIES

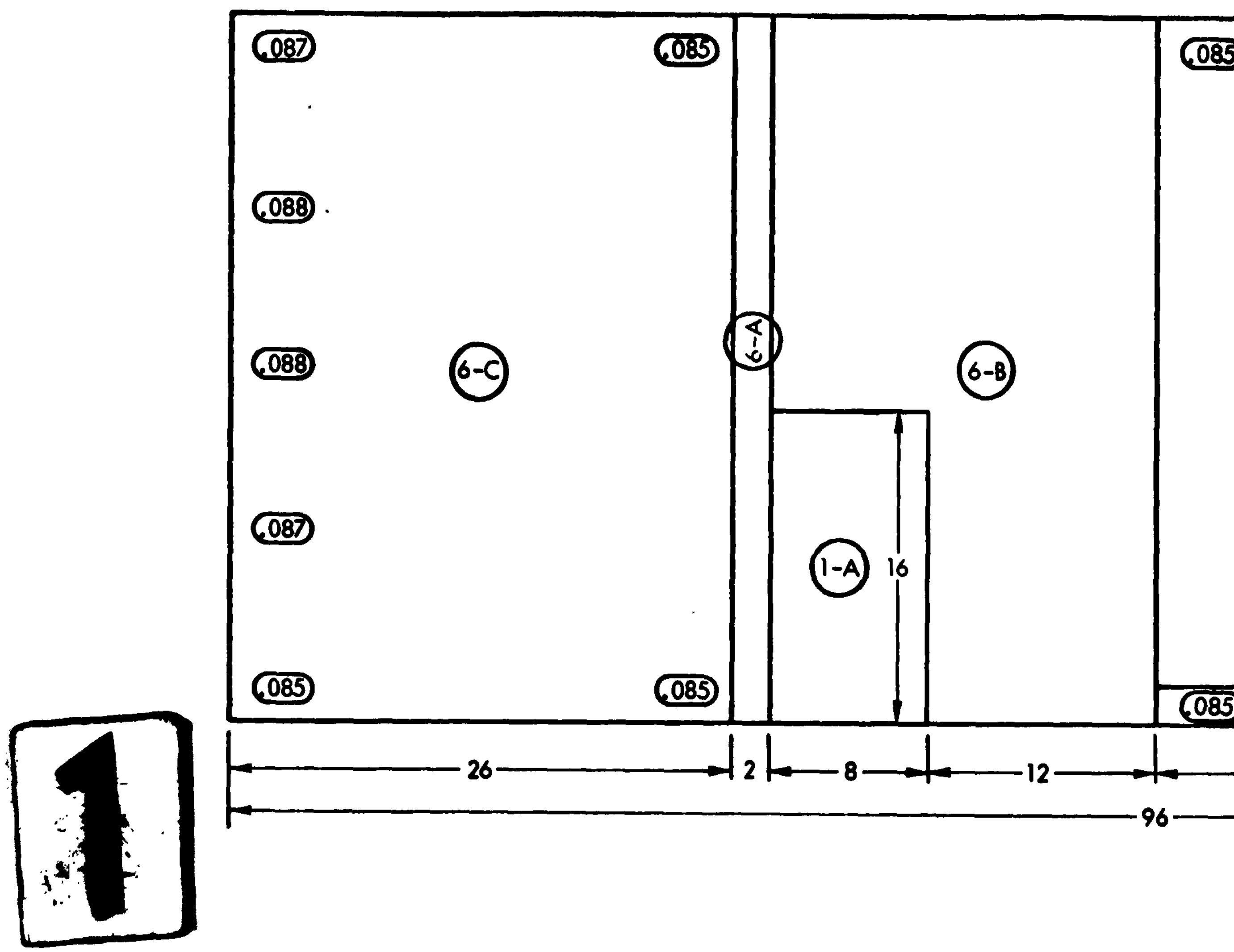
5 MACHINABILITY

6 FORMABILITY
- 6-A BEND AND SURFACE
- 6-B BEND AND JOGGLE
- 6-C BEND AND STRETCH
- 6-D HYDRO PRESS
- 6-E HOT SIZE
- 6-F DIMPLE

N: WHITE CORROSIVE PRODUCT BOTH SIDES. DIFFERENTIAL ETCH THREE (3) PLACES. (BELIEVED DUE TO ETCHING RACK.)

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.090
ACTUAL GAGE	.089 - .100
ACTUAL SIZE	37 x 88
HEAT NO.	V1784B
SHEET NO.	4
FLATNESS	LESS THAN 1%
VENDOR	TMCA

INSPECTION AND LAYOUT



TEST CODES

① MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

② SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

③ RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

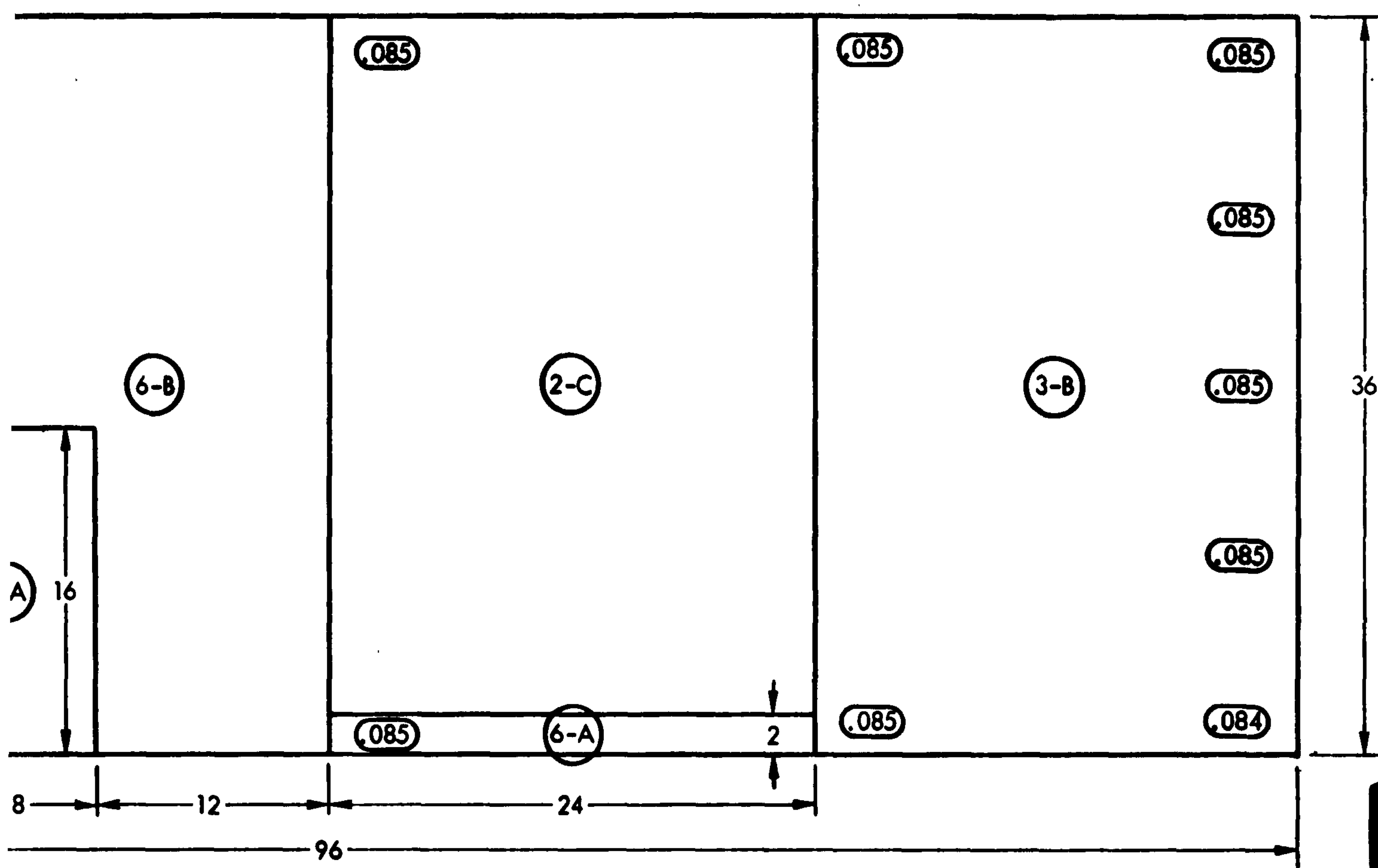
④ FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

⑤

⑥

THICKNESS MEASUREMENTS	SURFACE CONDITION: PRODUCTION ACCEPTABLE

INSPECTION AND LAYOUT PRINT FT-2-83



2

ST CODES

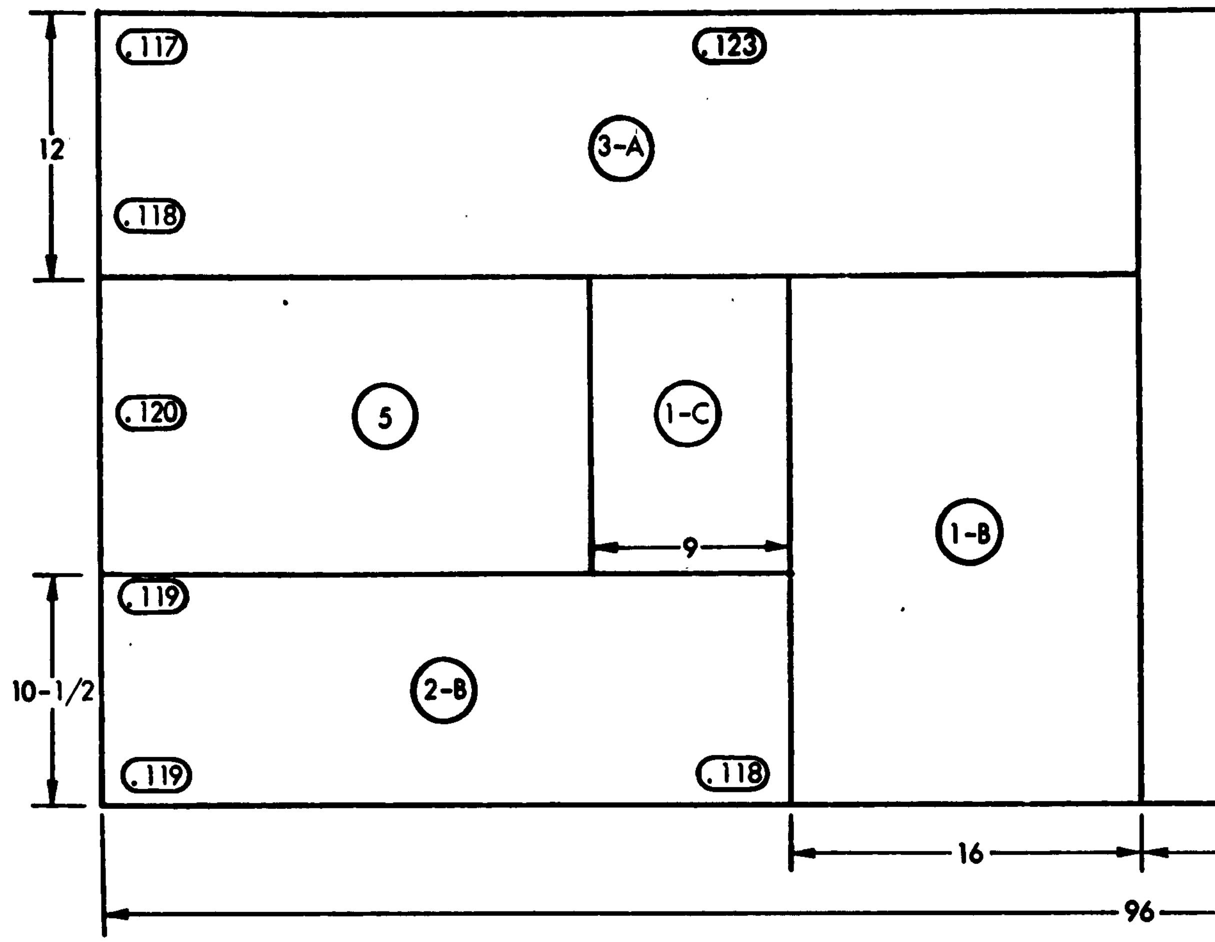
' WELD	(5) MACHINABILITY
T	(6) FORMABILITY
A	6-A BEND AND SURFACE
/ELD	6-B BEND AND JOGGLE
DING PROCEDURE	6-C BEND AND STRETCH
CTS OF CHEMISTRY	6-D HYDRO PRESS
P PROPERTIES	6-E HOT SIZE
	6-F DIMPLE

: PRODUCTION ACCEPTABLE

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.090
ACTUAL GAGE	.084 - .088
ACTUAL SIZE	36 x 96
HEAT NO.	V1913
SHEET NO.	5
• FLATNESS	LESS THAN 1%
VENDOR	TMCA

1

INSPECTION AND LAYOU



TEST CODES

(1) MECHANICAL PROPERTIES
1-A ROOM TEMPERATURE
1-B ROOM & ELEVATED TEMPERATURE
1-C CREEP PROPERTIES

(2) SURFACE CONTAMINATION
2-A BEND AND TENSILE
2-B FATIGUE
2-C FABRICATION PRACTICES

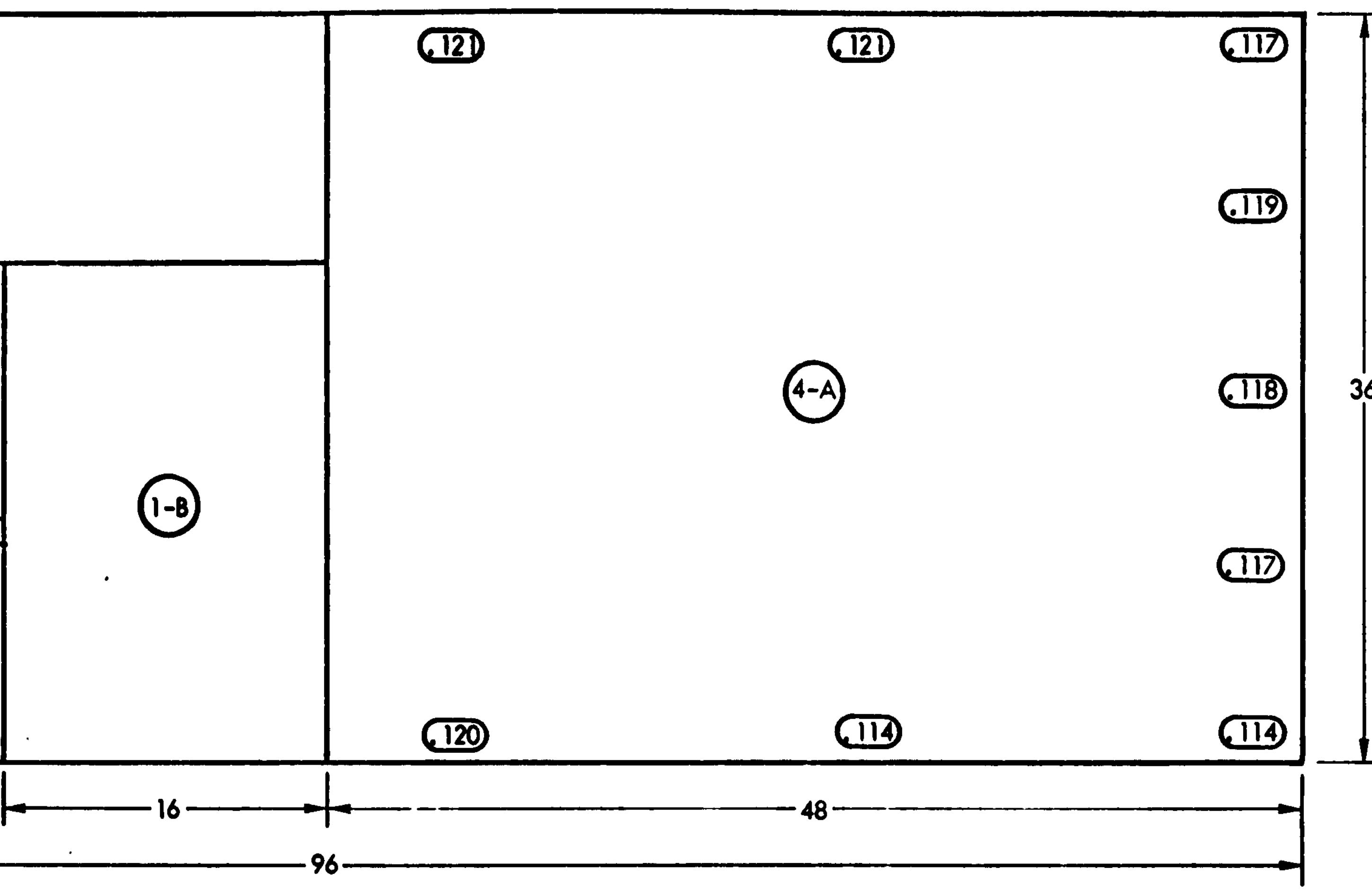
(3) RESISTANT WELD
3-A SPOT
3-B SEAM

(4) FUSION WELD
4-A WELDING PROCEDURE
4-B AFFECTS OF CHEMISTRY
4-C CREEP PROPERTIES

(5)

(6)

THICKNESS MEASUREMENTS	SURFACE CONDITION: WHITE CORROSIVE PRODUCT HANDLING SCRATCHES NEA



2

EST CODES

T WELD

OT

M

WELD

LDING PROCEDURE

ECTS OF CHEMISTRY

EP PROPERTIES

5 MACHINABILITY

6 FORMABILITY

6-A BEND AND SURFACE

6-B BEND AND JOGGLE

6-C BEND AND STRETCH

6-D HYDRO PRESS

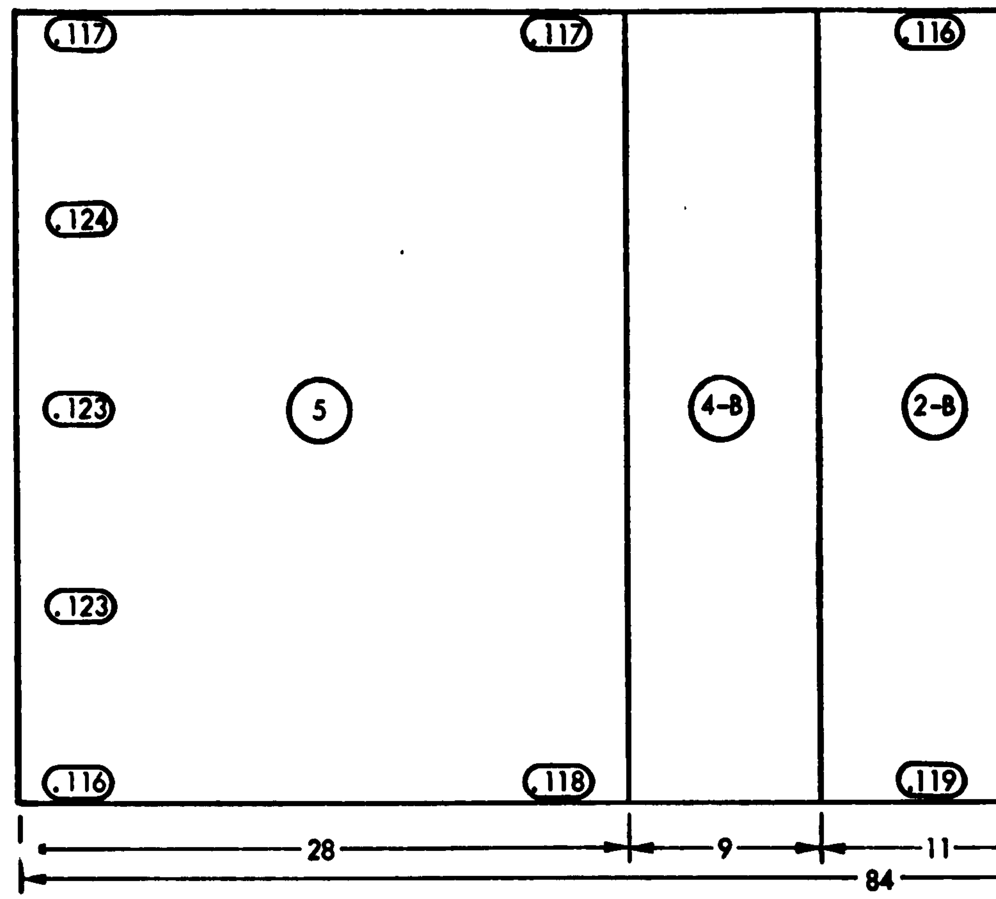
6-E HOT SIZE

6-F DIMPLE

N: WHITE CORROSIVE PRODUCT BOTH SIDES OF SHEET.
HANDLING SCRATCHES NEAR RIGHT HAND END.

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.125
ACTUAL GAGE	.114 - .123
ACTUAL SIZE	36 x 96
HEAT NO.	V1813M
SHEET NO.	3
FLATNESS	1%
VENDOR	TMCA

INSPECTION AND LAYOU



1

TEST CODES

① MECHANICAL PROPERTIES
- 1-A ROOM TEMPERATURE
- 1-B ROOM & ELEVATED TEMPERATURE
- 1-C CREEP PROPERTIES

② SURFACE CONTAMINATION
- 2-A BEND AND TENSILE
- 2-B FATIGUE
- 2-C FABRICATION PRACTICES

③ RESISTANT WELD
- 3-A SPOT
- 3-B SEAM

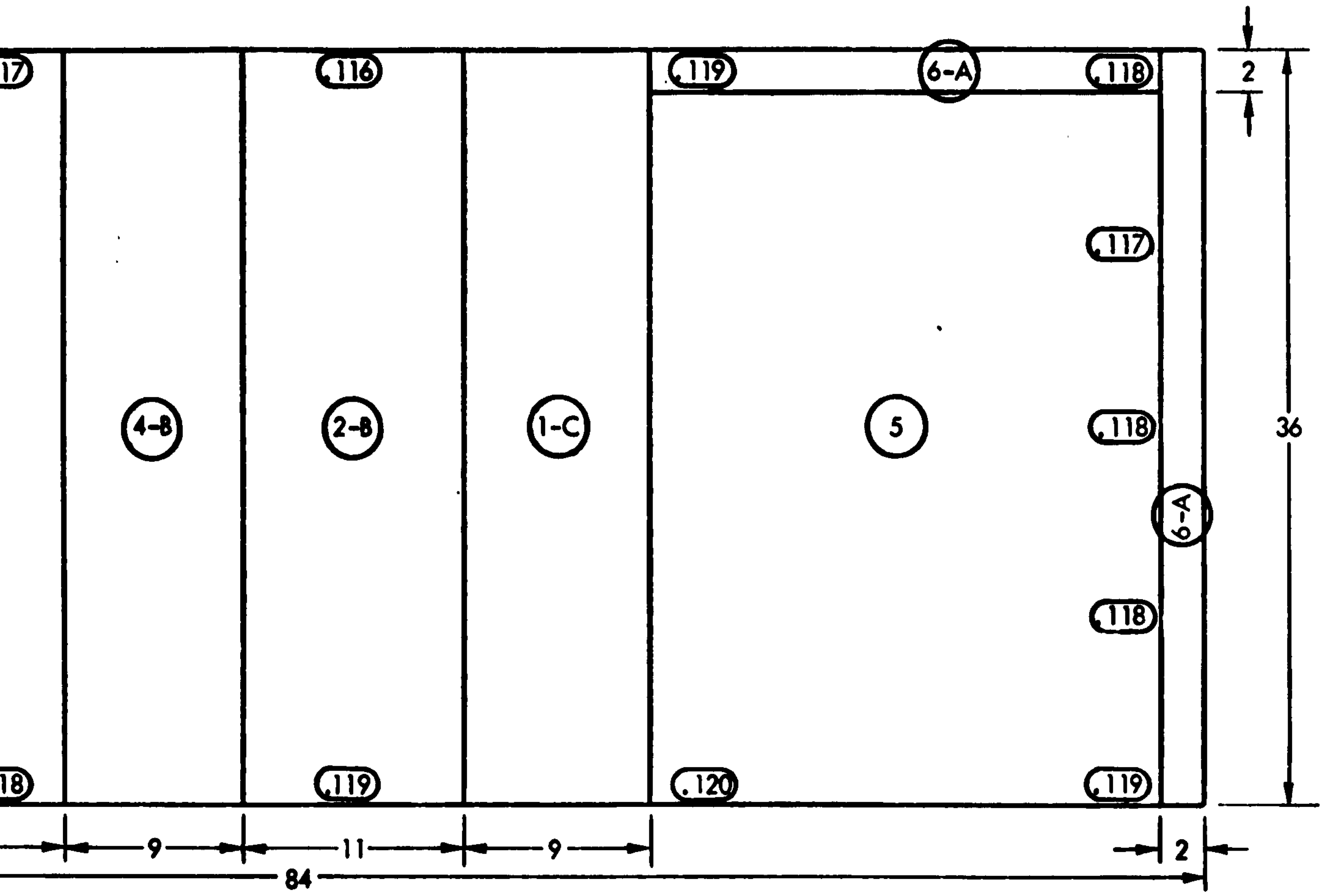
④ FUSION WELD
- 4-A WELDING PROCEDURE
- 4-B AFFECTS OF CHEMISTRY
- 4-C CREEP PROPERTIES

⑤

⑥

THICKNESS MEASUREMENTS	SURFACE CONDITION: WHITE CORROSIVE PRODUCT B

INSPECTION AND LAYOUT PRINT FT-3-85



2

EST CODES

T WELD
OT
M
VELD
DING PROCEDURE
ECTS OF CHEMISTRY
EP PROPERTIES

5 MACHINABILITY

6 FORMABILITY

6-A BEND AND SURFACE
6-B BEND AND JOGGLE
6-C BEND AND STRETCH
6-D HYDRO PRESS
6-E HOT SIZE
6-F DIMPLE

I: WHITE CORROSIVE PRODUCT BOTH SIDES

MATERIAL DATA	
ALLOY	5Al. - 5Sn. - 5Zr.
NOMINAL GAGE	.125
ACTUAL GAGE	.116 - .124
ACTUAL SIZE	36 x 84
HEAT NO.	V1785B
SHEET NO.	2
FLATNESS	LESS THAN 1%
VENDOR	TMCA

APPENDIX II

METALLURGICAL EVALUATIONS

ABSTRACT

Initial data is presented giving tensile properties of both the 7-12 and the 5-5-5 alloys at room temperature, 900°F, and 1100°F. Supplier mechanical properties and chemical compositions are given for all the sheet to be evaluated under this contract.

1. **INTRODUCTION**: Appendix II contains the Metallurgical evaluations being conducted on the 5Al-5Sn-5Zr and 7Al-12Zr super alpha titanium sheet alloys. Target properties, Supplier chemical analyses and mechanical properties, data obtained, and future work are presented for the materials being studied.

2. **SCOPE**: Room temperature tensile properties will be determined on all sheet received for this program. In addition, the tensile properties of selected sheets (4 of each alloy) will be determined at 900°F and 1100°F. All tensile testing will be performed in both the longitudinal and transverse directions.

2.1 Creep properties will also be determined from the same parent material as that used for elevated temperature tensile testing. Deformation for times from 10 to 1000 hours will be measured at 900°F and 1100°F for the longitudinal grain direction in two sheets; duplicate specimens will be tested at one stress level and one temperature to check transverse properties in the same two sheets. Longitudinal creep properties will be checked at two stress levels at 900°F and 1100°F for the material of the remaining two sheets.

2.2 The possibility of picking-up surface contamination during processing particularly in the case of the 7-12 alloy, will be investigated. In addition, the effect of thermal exposure, for times to 1000 hours and temperatures to 1000°F, on the fatigue and tensile properties and minimum bend radius will be studied.

2.3 Metallographic examinations will be performed, where required, in support of the overall program.

3. MATERIAL: Listed below are the target tensile properties for the 7Al-12Zr and 5Al-5Zr-5Sn alloys.

Alloy	Ftu	Fty	% Elongation in 2"	Minimum Bend Radius X Thickness
5-5-5	120	110	12	4.5T below .070 5.0T, .070 and above
7-12	120	110	10	5.0T

3.1 Supplier chemical properties are given in Tables I and II. Mechanical properties, as determined by the producer are given in Tables III and IV.

4. RESULTS: Results of the mechanical property determination performed to date for the 5-5-5 alloy at room temperature, 900°F, and 1100°F are given in Tables V and VI. All test values obtained exceed the target properties. Reported values are an average of five specimens.

4.1 Tensile results for the 7-12 alloy determined to date, at room temperature, 900°F and 1100°F are given in Tables VII and VIII. As in the case of the 5-5-5 test results, all values obtained for the 712 exceeded the target properties.

4.2 Both these alloys exhibit excellent strength retention at both 900°F and 1100°F after exposure to temperature for 1/2 hour. At 1100°F both alloys still possess 60-65% of their room temperature tensile ultimate. In the case of total elongation versus temperature, both alloys exhibit better elongation at 900°F than at 1100°F. This is almost identical to the total elongation versus temperature relationship demonstrated by another alpha alloy, 5Al-2.5 Sn. With this alloy a rather sharp increase

in total elongation is experienced at 900°F to 1000°F but as the temperature increases above 1000°F, the elongation decreases quite rapidly.

5.0 FUTURE WORK: During the next reporting period, determination of tensile properties will be completed. Creep, fatigue, and thermal stability studies will be initiated.

TABLE I

TMCA CHEMICAL ANALYSES-ALLOY 5Al-5Zr-5Sn

HEAT	SHEET	NOMINAL GAGE	CARBON	IRON	NITROGEN	ALUMINUM	ZIRCONIUM	TIN	HYDROGEN
V-1785	1	.020	.015	.05	.025	4.9	5.1	4.9	.008
V-1313	1	.020	.013	.05	.023	5.0	5.1	4.9	.007
V-1313	6	.020	.013	.05	.023	5.0	5.1	4.9	.010
V-1785	3	.040	.015	.05	.025	4.9	5.1	4.9	.007
V-1313	5	.040	.013	.05	.023	5.0	5.1	4.9	.004
V-1313	9	.040	.013	.05	.023	5.0	5.1	4.9	.005
V-1734	1	.062	.012	.05	.026	5.0	5.1	5.0	.005
V-1734	2	.062	.012	.05	.026	5.0	5.1	5.0	.006
V-1313	4	.062	.013	.05	.023	5.0	5.1	4.9	.005
V-1734	4	.090	.012	.05	.026	5.0	5.1	5.0	.004
V-1913	5	.090	.025	.05	.009	5.2	5.3	4.9	.004
V-1785	2	.125	.015	.05	.025	4.9	5.1	4.9	.004
V-1313	3	.125	.013	.05	.023	5.0	5.1	4.9	.004

TABLE II

SUPPLIER CHEMICAL ANALYSES-ALLOY 7Al-12Zr

SUPPLIER	HEAT	SHEET	NOMINAL GAGE	CARBON	IRON	NITROGEN	ALUMINUM	ZIRCONIUM	HYDROGEN
TMCA	V-1786	4	.020	.017	.05	.014	6.7	11.9	.007
TMCA	V-1787	3	.020	.021	.06	.014	6.7	11.9	.007
RMI	32558	3174-4	.020	.02	-	.004	6.93	12.04	.0051
TMCA	V-1787	5	.040	.021	.06	.014	6.7	11.9	.005
TMCA	V-1788	3	.040	.015	.05	.016	6.9	11.8	.007
RMI	32558	3175-7	.040	.02	-	.004	6.93	12.04	.0044
TMCA	V-1786	3	.062	.017	.05	.014	6.7	11.9	.004
TMCA	V-1786	4	.062	.017	.05	.014	6.7	11.9	.005
RMI	32558	3176-4	.063	.02	-	.004	6.93	12.04	.0033
RMI	32558	3176-7	.063	.02	-	.004	6.93	12.04	.0035
TMCA	V-1787B	2	.090	.021	.06	.014	6.7	11.9	.004
TMCA	V-1787T	2	.090	.021	.06	.014	6.7	11.9	.004
TMCA	V-1788	2	.125	.015	.05	.016	6.9	11.8	.003
TMCA	V-1914	4	.125	.026	.07	.021	7.0	11.9	.003
RMI	32558	3179-5	.125	.02	-	.004	6.98	12.04	.0034

TABLE III
TMCA MECHANICAL PROPERTIES-ALLOY 5Al-5Zr-5Sn

HEAT	SHEET	NOMINAL GAGE	ROLLING DIRECTION	Ftu (Ksi)	Fty (Ksi)	% ELONGATION IN 2"
V-1785	1	.020	L	127,300	116,600	14.5
		"	T	126,100	116,100	16.0
V-1313	1	"	L	126,300	115,600	16.0
		"	T	127,300	117,600	15.5
V-1313	6	"	L	129,600	113,400	16.5
		"	T	129,200	119,000	15.0
V-1735	3	.040	L	124,000	113,300	16.0
		"	T	124,400	115,200	15.5
V-1313	5	"	L	127,100	116,300	14.5
		"	T	127,700	116,900	16.0
V-1313	9	"	L	123,700	113,000	15.0
		"	T	129,200	113,500	16.0
V-1784	1	.062	L	125,100	116,500	16.5
		"	T	124,700	115,000	15.0
V-1784	2	"	L	119,000	115,900	17.0
		"	T	125,300	116,000	17.0
V-1813	4	"	L	127,300	116,100	12.0
		"	T	126,900	114,700	16.0
V-1784	4	.090	L	125,700	112,100	16.5
		"	T	124,900	115,000	16.0
V-1913	5	"	L	123,100	111,600	16.5
		"	T	123,500	113,800	17.5
V-1735	2	.125	L	122,600	111,900	17.0
		"	T	123,000	112,300	17.0
V-1813	3	"	L	124,800	114,300	17.0
		"	T	124,900	116,300	16.5

TABLE IV

SUPPLIER MECHANICAL PROPERTIES-ALLOY 7Al-12Zr

SUPPLIER	HEAT	SHEET	NOMINAL GAGE	ROLLING DIRECTION	Ftu(Ksi)	Fty(Ksi)	% ELONGATION in 2"
TMCA	V-1786	4	.020	L	140,300	129,700	17.0
			"	T	133,700	129,200	16.5
TMCA	V-1787	3	"	L	141,100	131,200	16.0
			"	T	141,000	132,300	16.5
RMI	32553	3174-4	"	L	125,000	117,500	13.50
			"	T	123,500	116,000	13.25
TMCA	V-1787	5	.040	L	135,700	127,300	16.0
			"	T	136,600	126,000	17.5
TMCA	V-1788	3	"	L	142,100	129,300	14.0
			"	T	133,900	123,400	16.0
RMI	32553	3175-7	"	L	131,000	122,500	15.5
			"	T	133,000	126,000	15.5
TMCA	V-1786	3	.062	L	137,500	127,100	16.0
			"	T	137,200	127,200	17.0
TMCA	V-1786	4	"	L	137,300	126,300	16.0
			"	T	136,500	126,100	16.5
RMI	32558	3-176-4	.063	L	133,500	125,500	16.3
			"	T	135,500	129,500	15.0
RMI	32558	3-176-7	"	L	130,500	122,500	14.25
			"	T	135,000	125,000	14.0
TMCA	V-1787B	2	.090	L	130,500	121,300	17.5
			"	T	126,900	120,700	17.0
TMCA	V-1787T	2	"	L	137,300	126,200	16.0
			"	T	135,500	125,500	17.0
TMCA	V-1788	2	.125	L	136,900	126,800	13.5
			"	T	139,900	128,400	13.0
TMCA	V-1914	4	"	L	138,700	129,100	15.0
			"	T	136,100	127,800	16.0
RMI	32558	3179-5	"	L	132,000	122,000	17.5
			"	T	134,000	125,000	17.0

TABLE V

NAA MECHANICAL PROPERTIES OF TMCA ALLOY 5Al-5Zr-5Sn at R.T., 900, and 1100°F.

HEAT	SHEET	GAGE	ROLLING DIRECTION	Ftu(Ksi) RT	Ftu(Ksi) 900°F	Ftu(Ksi) 1100°F	Fty(Ksi) RT	Fty(Ksi) 900°F	Fty(Ksi) 1100°F	%Elongation in 2" RT	%Elongation in 2" 900°F	%Elongation in 2" 1100°F
V-1313	9	.040	L	126.1	79.2	75.8	116.1	61.9	58.5	14.8	22.3	20.2
			T	124.9	80.6	76.9	113.6	61.4	57.7	15.1	26.4	21.0
V-1734	2	.063	L	125.6	80.0	76.7	116.7	61.6	59.4	14.6	27.1	22.5
			T	125.5	79.6	77.0	117.1	60.9	58.3	15.9	26.4	21.8
V-1734	4	.090	L	126.3	73.3	80.1	113.3	62.4	62.7	14.2	29.9	30.5
			T	125.9	83.4	85.0	114.7	62.5	62.9	16.8	26.2	26.4
V-1313	3	.125	L	123.5	82.4	73.0	112.5	62.5	59.4	18.2	31.0	25.3
			T	123.5	80.1	75.9	114.9	63.1	59.7	17.7	31.4	26.1

TABLE VI

NAA MECHANICAL PROPERTIES OF TMCA ALLOY 5Al-5Zr-5Sn At R.T.

HEAT	SHEET	GAGE	ROLLING DIRECTION	FTU(Ksi)	FTY(Ksi)	%Elongation in 2"
V-1735	1	.020	L	124.6	116.2	12.9
			T	124.5	115.3	17.0
V-1735	3	.040	L	121.9	113.4	17.7
			T	120.5	113.5	17.7
V-1313	4	.063	L	125.1	116.9	16.0
			T	125.2	116.3	16.4
V-1735	2	.125	L	121.4	113.1	17.5
			T	122.2	115.7	16.8

TABLE VII
NAA MECHANICAL PROPERTIES OF TMCA ALLOY 7Al-12Zr AT R.T., 900, and 1,100°F.

HEAT	SHEET	GAGE	ROLLING DIRECTION	Ftu(Ksi) RT	Ftu(Ksi) 900°F	Ftu(Ksi) 1100°F	Fty(Ksi) RT	Fty(Ksi) 900°F	Fty(Ksi) 1100°F	%Elongation in 2" RT	%Elongation in 2" 900°F	%Elongation in 2" 1100°F
V-1733	3	.040	L	139.3	93.1	90.0	132.3	73.1	71.9	15.2	26.3	24.3
			T	133.7	89.0	86.2	123.6	75.1	69.9	16.2	23.3	25.1
V-1737B	2	.090	L	132.6	88.5	86.1	125.3	74.6	73.5	15.1	28.2	24.4
			T	123.0	82.6	80.4	123.3	74.0	69.3	15.6	23.0	27.3
V-1733	2	.125	L	135.9	92.3	91.5	127.3	74.7	68.5	15.3	23.1	21.0
			T	137.3	94.3	92.6	129.6	76.3	71.0	15.3	26.4	19.9

TABLE VIII
NAA MECHANICAL PROPERTIES OF ALLOY 7Al-12Zr At R.T.

SUPPLIER	HEAT	SHEET	GAGE	ROLLING DIRECTION	Ftu(Ksi)	Fty(Ksi)	%Elongation in 2"
TMCA	V-1737T	2	.090	L	135.5	126.4	17.1
				T	134.3	126.8	16.4
TMCA	V-1914	4	.125	L	136.3	129.9	17.2
				T	135.5	129.7	16.3
RMI	32558	3179-5	.125	L	132.3	125.7	17.3
				T	135.3	127.3	17.4

APPENDIX III

FORMABILITY

ABSTRACT

Bend tests were completed during this reporting period and the minimum bend radii was within target minimum bend radii with the exception of one sheet. The sheet was T.M.C.A. supplied 7-12 alloy, .090 gage heat V1787B, sheet A7190-2 which is identified by N.A.A. as Sheet #69.

1. INTRODUCTION: Formability evaluations to be conducted on the 5Al-5Sn-5Zr and 7Al-12Zr super alpha titanium sheet alloys under this program are; material preparation, bend and surface, short bend, long bend, joggle, wrap stretch, hydro press, benching and hot sizing. Formability tests are conducted in the production departments to establish data based on production techniques and equipment, increase production "know how" and reduce the usual laboratory to manufacturing transition problems when the new alloys are released for production parts.

2. MATERIAL PREPARATION: During the shearing, sawing and preparation of edges of formability test specimens from sheet of both alloys the time consumed and results were very similar to the 8 Mn Titanium. Requirements for edge preparation and cleaning will be established upon completion of the formability tests. At this time it would appear that; power brake formed parts would be deburred by hand or by tumbling and shrink and stretch flanges of formed parts would require polished edges, cleaning of the alloys can be accomplished by the use of a uninhibited heavy duty alkaline cleaner followed by a cold top water rinse.

2.1 Unless otherwise noted in the presentation of data for specific evaluations the surface condition of specimens are "as received" for the formability tests.

3. BEND TESTS

3.1 General: Bend tests were conducted at room temperature using conventional production power brakes and tooling on longitudinal and transverse bend and surface, short bends and long bend specimens testing of all gages of both alloys. Specimens were formed through 105° with the surfaces alternated to determine the extent one surface versus the other affects the minimum bend radii as well as the relationship of the bend axis to the final rolling direction of the sheet.

Results: The effect the varying of the surfaces of the sheet had on establishing minimum bend radii was negligible. The relationship of the specimen bend axis did affect the minimum bend radii by as much as 1T for some sheets of both alloys. Reference Figures 3 and 4 pages 60 and 61 N.A.A. Sheet numbers 65,73 and 74.

3.2 Minimum Bend Radii: The minimum bend radii obtained by N.A.A. range from 3.0 to 6.0T for the 7-12 alloy and 2.5 to 4.0T for the 5-5-5 alloy. Reference Figure 3 and 4, page 60 and 61. Target bend radii is 4.5T to .070 gage and 5.0T above .070 for the 5-5-5 and 5T for all gages of the 7-12 alloy. Efforts are being made to determine the reason(s) for the 6.0T bend radii for N.A.A. Sheet #69, T.M.C.A. supplied 7-12 alloy,.090 gage, heat V1787B, Sheet #A7190-2, which is the only sheet that exceeded the target minimum bend radii for the alloys. The first step was to pickle .003 from each surface and subject the specimen to bend testing. This cycle was repeated until a total of .012 had been removed from each surface with a 0.5T improvement in minimum bend radii. Other investigations, such as determining

the oxygen content of the sheet, will be conducted to determine if the bend radii obtained for this sheet is to be expected for this alloy. Should the sheet, N.A.A. #69, be proven the exception and removed from the bend test data obtained by N.A.A. for the 7-12 alloy the following would apply.

ALLOY	MINIMUM BEND RADII
7-12	4.5T
5-5-5	4.0T

3.3 Spring-back: The spring-back data for the alloys did not establish a pattern for the L & T specimens of any given gage of either alloy during the bend tests. Spring-back varied from 9 to 18° for the 5-5-5 alloy and 6 to 23° for the 7-12 alloy. Spring-back data will be recorded for the remaining formability tests and plotted by alloys, gages and direction of the bend axis to the final rolling direction of the sheet. The intent is to obtain a pattern for the relief of forming tools to compensate for spring-back.

3.4 Comparison of Supplier and N.A.A. Bend Radii: N.A.A.'s minimum bend radii are larger for the majority of sheets than the minimum bend radii reported by the suppliers. This may be due to N.A.A. reporting the actual radii formed in the specimens versus the suppliers reporting the radius of the punch used for bend tests. Reference Pages 7 and 8, paragraph 4.8 for a comparison of N.A.A. and suppliers minimum bend radii

3.5 Figures 3 and 4: The percentages of production acceptable bends given in Figures 3 and 4, pages 60 & 61 are based on a range of a minimum of six bends for the "zero" percentages posted to a maximum of thirty bends for the 100 percent postings. The approximate number of bends total; 1000 for the 7-12 alloy and eight hundred for the 5-5-5 alloy.

4. FORMABILITY TESTS TO BE CONDUCTED: The bend test data presented represents the formability tests completed during this reporting period. The remainder of the Formability Tests (Reference Paragraph 1 , page 56) will be completed and reported, including data obtained, conclusions and recommendations, in the next reporting period of 28 April 1962.

K&E 10 X 10 TO THE ½ INCH 359-11

FIGURE 3

MINIMUM BEND RADII 7Al.-12Zr ALLOY

PERCENT OF PRODUCTION ACCEPTABLE BENDS FOR VARIOUS SPECIMEN RADII

CODE: L = INDICATES BEND AXIS TRANSVERSE TO THE FINAL ROLLING DIRECTION
T = INDICATES BEND AXIS PARALLEL TO THE FINAL ROLLING DIRECTION

NAA SHEET #	VENDOR	GAGE		0 T		1 T		2 T		3 T		4 T		5 T		6 T
87	TMCA	.125	L								0	100				
			T								0	100				
72	RMI	.125	L								0	100				
			T								0	100				
70	TMCA	.090	L					0		20	100					
			T					0		0	100					
69	TMCA	.090	L											0	80	100
			T											0	70	100
66	TMCA	.062	L					0	90	90	100					
			T					0	90	100						
68	RMI	.062	L				0	30	70	100						
			T				0	0	40	80	100					
67	RMI	.062	L				0	80	90	100						
			T				0	60	80	100						
66	TMCA	.062	L					0	50	80	100					
			T					0	0	40	100					
65	RMI	.040	L				0	20	50	90	100					
			T				0	20	40	60	70	90	100			
63	TMCA	.040	L				0	0	10	70	100					
			T				0	20	50	100						
62	RMI	.020	L				0	50	80	100						
			T				0	0	30	70	100					
61	TMCA	.020	L				0	50		80	100					
			T				0	0		30	60	100				
60	TMCA	.020	L							0		60	100			
			T							0		40	100			

SPECIMEN BEND RADII VS THICKNESS

FIGURE 4

MINIMUM BEND RADII - 5AL. - 5Sn. 5Zr. ALLOY - TMCA MATERIAL

PERCENT OF PRODUCTION ACCEPTABLE BENDS FOR VARIOUS SPECIMEN RADII

CODE:
L INDICATES BEND AXIS TRANSVERSE TO THE FINAL ROLLING DIRECTION
T INDICATES BEND AXIS PARALLEL TO THE FINAL ROLLING DIRECTION

NAR. SHEET	GAGE		0T		1T		2T		3T		4T
85	.125	L							0		100
		T							0		100
83	.090	L						0	80	100	
		T						0	80	100	
82	.090	L						0	10	100	
		T						0	20	100	
81	.062	L				0	100				
		T				0	90	100			
80	.062	L				0	100				
		T				0	90	100			
79	.062	L				0	90	100			
		T				0	70	100			
77	.040	L					0	10	40	70	100
		T					0	0	0	50	100
76	.040	L				0	20	50	90	100	
		T				0	20	60	60	90	100
75	.020	L					0		60		100
		T					0		60		100
74	.020	L			0	40	80		100		
		T			0	0	0		50		100
73	.020	L			0	0	0		60		100
		T			0	50	80		100		

SPECIMEN BEND RADII VS THICKNESS

APPENDIX IV

MACHINABILITY

ABSTRACT

This Appendix IV outlines the Milling and Drilling tests to be conducted under this program.

1. **INTRODUCTION:** The information presented herewith is an outline of the test program to determine the drilling and milling characteristics of 5Al-5Sn-5Zr and 7Al-12Zr and the status of the investigation to date.

2. **PURPOSE:** The material and cutting surface configuration of drills and end mill cutters will be varied to determine what set of conditions will give the best tool life and surface finish on the material being tested.

3. **STATUS OF TEST PROGRAM:** The evaluation of drills is approximately thirty percent complete; however, the results obtained to date are of a statistical nature and are not considered reportable at this time.

The evaluation of end mills has not been started.

4. TEST PROCEDURE:

4.1 General:

Materials - 5Al-5Sn-5Zr Titanium Alloy
7Al-12Zr Titanium Alloy

Gage - .125 inches

Specimen Size - 4 X 7 inches

4.2 Drilling Test: A number 30 drill will be used to drill holes through the .125 inch test specimen.

Drill Materials - M7
M3 (Type II)

Drill Performance - will be rated by the number of holes drilled before the hole is considered to be under or oversize, has excessive burr, or the drill breaks.

4.2.4 The Box-Wilson Surface Response* statistical method will be used to evaluate the drills, employing the following variables:

a. Speed
b. Feed
c. Coolant
d. Web Thinning
e. Point Angle
f. Part Temperature
g. Clearance Angle

4.3 MILLING TESTS: Milling tests will be performed on .125 inch panels stacked to a height of one inch.

End Mill Size - $1\frac{1}{2}$ inches

End Mill Materials - M-2 Standard High Speed Steel
T-15 Tool Steel

End Mill Performance will be rated according to the number of inches traversed at a .125 inch depth of cut, before a .010 inch wide wear land develops or the surface finish is not considered acceptable.

4.3.1 The Box-Wilson Surface Response* statistical method will be used to evaluate the end mills, taking into account the following variables:

a. Speed
b. Feed
c. Coolant
e. Secondary Angle
f. Part Temperature
g. Primary Land Width

* The Box-Wilson Surface Response work sheet is a two-factorial statistically designed experiment to determine optimum conditions.

5. FUTURE WORK: Machinability evaluations will be completed and reported in the next reporting period of 28 April 1962.

APPENDIX V

DIMPLING

ABSTRACT

The dimpling tests conducted to date indicate that single action equipment is not capable of dimpling the alloys.

1. **INTRODUCTION:** Presented herewith is an outline of the test program to determine dimpling characteristics of 5Al-5Sn-5Zr and 7Al-12Zr titanium alloys and the status of the investigation to date.

2. **PURPOSE:** Determine if dimples of acceptable quality can be produced using standard dimpling equipment and dimple dies.

3. **STATUS OF TEST PROGRAM:** To date several tests have been conducted on single action and triple action equipment to establish the scope of the test program. It appears that the single action equipment may not be capable of dimpling either of the materials or gage thickness to be tested. Cracked dimples were obtained both at room temperature and 800 F. On the triple action dimpler it may be possible to produce crack-free dimples at 800 F. The testing program now in progress is not complete enough for reporting at this time.

4. **TEST PROGRAM OUTLINE**

4.1 **General**

Materials	- 5Al-5Sn-5Zr Titanium Alloy
	- 7Al-12Zr
Gage Thickness (Inches)	-.020
	.040
Specimen Size	- 1 X 6 inch test strips
Dimple Size	- Number 10 screw (unless otherwise noted)
Equipment	- Stationary - Single Action Triple Action

4.2 Establish Machine Settings: Machine settings (heat, dwell time, pressure) will be varied in a logical manner to establish parameter which will produce dimples that are crack-free and will not distort the test piece.

In addition to visual examination, specimens will be subjected to penetrant inspection and macroexamination.

5. FUTURE WORK: The dimpling results obtained, conclusions and recommendations will be presented in the next progress report.

APPENDIX VI

FUSION WELDING

ABSTRACT

The super alpha titanium 5-5-5 and 7-12 alloys have good weldability. Sound welds can be produced by usual pickle cleaning of the alloys and draw filing of the edge or joint preparation prior to welding. Both manual and machine gas tungsten arc welding, using sheared strips of sheet for filler metal have been satisfactory.

1. INTRODUCTION: The evaluation of the fabrication characteristics of the Ti-5Al-5Sn-5Zr and Ti-7Al-12Zr super alpha alloys will include fusion welding by the gas tungsten arc process to determine weldability, elevated temperature static strength and creep properties of weldments, and weld metal quality of the alloys. Welds will be made in each alloy in .040" and .125" nominal thicknesses for weldability trials, weld quality examinations, and static mechanical property tests; and in .090" thickness for creep tests. Manual and machine gas tungsten arc welds were made in each alloy and thickness to establish weld parameters.

2. RESULTS OF TESTS OF Ti-5Al-5Sn-5Zr ALLOY:

2.1 Weldability: Overall weldability of the 5-5-5 alloy is excellent including good metal flow and wetting of the base metal. Welding characteristics of the alloy are almost identical to those of the Ti-5Al-2½Sn alloy. All of the alpha alloys tend to bridge easily and this characteristic makes puddling and control of the weld pool relatively easy.

2.1.1 The welding of the 5-5-5 alloy is not more difficult nor is it different from the welding of other alpha titanium alloys. However, the weldability tests conducted and the welding of the coupons described below will not establish cracking tendencies of the weld metal or heat affected zone, because the stresses due to restraint during welding are relatively low in the simple specimen welds.

2.2 **Preparation For Welding:** The cleanliness of the edge or joint preparation of all titanium alloy weldments is a critical factor affecting soundness of the welds. The cleaning of the edge or joint preparation that is required for either alloy, following usual pickling and before welding, will be established. Initially the welds were checked for soundness by radiography, as a means of comparison. On the basis of the radiographic studies all of the welding is being done with adquate controls to insure that good weldments are produced for mechanical testing.

2.2.1 The pickling treatment used for descaling and cleaning the Ti-5Al-5Sn-5Zr was the same as normally used for alpha titanium alloys. That is, a nitric-hydroflouric solution was used with variations in time to effect either descaling or simple cleaning. The treatment seems to be adequate for both super alpha alloys.

2.2.2 The completion preparation of 5-5-5 alloy specimens for welding was: (1) The coupons were thoroughly cleaned (or descaled if necessary) by pickling after machining, (2) absolute cleanliness of the details was maintained after pickling, (3) the edge or joint preparation was draw filed, and (4) adequate inert gas shielding of the root of the weld and trailing the weld was provided for the time the weld was 500 degree F or above that temperature. (This includes protection of the molten metal by welding in an inert gas filled welding chamber).

2.2.3 The argon gas filled welding chamber was used for the welds exploring the edge preparation requirements. Using the chamber virtually eliminated the possibility that porosity or contaminants might be introduced in the welds by poor shielding during welding. Thus, radiographs of welds made on stock which had been pickle cleaned were compared with radiographs of welds made using more effective cleaning. Pickling only is satisfactory for some alloys in some instances, but was not enough preparation for the 5-5-5 alloy. Less porosity was evident in the welds which were made in stock which had draw filed edges and joint preparation.

2.2.4 It was possible to produce reasonably sound welds in pickled-only material by manual welding if the weld was puddled. However, this technique introduces more heat into the part and should be avoided since more contaminants will be taken into solution in the titanium weld metal in direct ratio to the time the weld remains hot.

2.2.5 The results of the tests as determined from radiographic examinations were that the welds made in stock having draw filed edges and joint preparation were decidedly more sound than others. The mechanical property tests yet to be completed will provide additional data for the evaluation of preweld preparation requirements.

2.2.6 In addition to the weld soundness checks, the quality of welds in each alloy will be further studied by metallographic examinations and hardness surveys.

2.3 **Mechanical Property Tests:** Mechanical properties of the welds in both alloys will be established by static tensile and bend tests of welded coupons. A second heat of each alloy will be used for similar but less extensive tests to determine if minor variations in chemical compositions will cause strength and ductility variations. The static tensile tests will be conducted at room temperature, 900° and 1100°F.

2.3.1 Creep specimens will be welded in each alloy for comparison with the unwelded creep specimen tests. The thickness of the unwelded specimens will be .090" and the welded specimens will be nominally the same thickness and will be made in the same heats of sheet insofar as possible.

2.3.2 Welding of the 5-5-5 alloy for welded mechanical property specimens has been completed. This includes (1) welds made in the argon filled welding chamber, under best conditions of shielding, (2) manual welds made outside the chamber with usual root and trailer gas shielding and (3) machine welds made for comparison and for elevated temperature tests. The machine welds were the most numerous. Each set of tensile and bend specimens has been welded in .040" and .125" thick sheet, and the creep specimens were made in .090" thick stock.

2.3.3 The welded 5-5-5 alloy specimens are in the process of being machined. This part of the work is about half completed.

2.3.4 All of the welds require filler metal to complete the joints. Filler wire was not available in the 5-5-5 alloy; therefore strips 1/8" to 3/16" wide were sheared from the .040" sheet to be used for filler metal in the welds. Using sheared strips for filler metal required that the machine welds as well as the manual welds be made by feeding the filler metal in by hand as the weld progressed. The sheared strips were thoroughly cleaned and carefully handled and stored. However, any sheared titanium edge on filler metal or on the base material used as the joint preparation is suspected of causing some porosity in the welds. Although the welds made have been reasonably sound, this factor must be considered when the data are evaluated.

3. RESULTS OF TESTS OF Ti 7Al-12Zr ALLOY

3.1 Weldability: The weldability of the 7-12 alloy is excellent both by manual and machine gas tungsten arc welding. The metal flows and wets well and has the same characteristics as the alpha titanium alloys such as Ti-5Al-2.5Sn and the Ti-5Al-5Sn-5Zr. As with those alloys the molten 7-12 alloy bridges easily and is easy to puddle and control.

3.1.1 The tests for weldability with the 7-12 alloy were the same as those for the 5-5-5. The welding was not difficult, either by manual or machine methods, and was very similar to welding other alpha titanium alloys. The coupons welded for the mechanical property tests do not reflect cracking tendencies of the alloys.

3.2 Preparation for Welding: The same pickling treatment is satisfactory for descaling and cleaning the Ti-7Al-12Zr alloy as used on other alpha titanium. A nitric-hydroflouric solution is used for different lengths of time to descale or simply clean.

3.2.1 The Ti-7Al-12Zr alloy should be prepared for welding by (1) cleaning thoroughly by pickling, (2) maintaining absolute cleanliness during setup and handling, (3) draw filing the edges to be joined and (4) providing adequate protection of the weld area from the air while it is hot, by inert gas shielding devices.

3.2.2 Welds made in the Ti-7Al-12Zr alloy to check on the cleaning of the edge preparation were also made in the inert gas filled welding chamber. Reasonably sound welds were made on stock which was pickle cleaned only, by manual welding, but the most consistantly sound welds were obtained, as with other titanium alloys, by draw filing the edges to be joined. The results are based on radiographs of the welds, but additional data will be provided by the evaluation of the welds made for mechanical property tests.

3.3 Mechanical Property Specimens: Welds for mechanical property test specimens in the Ti-7Al-12Zr alloy are not completed. The welds made in the welding chamber to establish cleaning requirements, and for comparison with welds made outside the chamber, have been completed. The manual and machine welds being made outside the chamber are each about half completed. The thicknesses being welded are .040" and .125" for tensile and bend specimens and .090" for the creep specimens.

3.3.1 All of the welds require that filler metal be added to the joint. Filler wire of the same composition was not procureable so .040" thick strips sheared to about 1/8" width are being used. These strips are cleaned as thoroughly as possible by pickling and wiping with solvents, and protected by careful handling and storage before use. However, sheared titanium edges, are suspected of being a source of porosity when presented in the welding zone either on the filler metal or as the base plate edge preparation. This variable must be considered in the eventual evaluation of weld specimen data.

4. FUTURE EVALUATIONS: Fusion welding evaluations as set forth in Paragraph 1 will be completed and reported in the next reporting period of 28 April 1962.

APPENDIX VII

RESISTANCE WELDING

ABSTRACT

Resistance welding tests are outlined in the Appendix and preliminary data indicates that the 5-5-5 alloy has a higher Tension/Shear Ratio than the 7-12 alloy.

1. INTRODUCTION: Presented herewith is an outline of the test program for evaluating spot welds and seam welds in 5Al-5Sn-5Zr and 7Al-12Zr titanium alloys and the status of the investigation to date.

2. PURPOSE: The purpose of the test program is to evaluate the following:

(a) The effects of machine settings on spot weld quality.

(b) The effects of elevated temperature on spot weld strength.

(c) The strength of spot welds at elevated temperature.

(d) The strength of seam weld joints.

3. STATUS OF TEST PROGRAM: Preliminary tests have been conducted to evaluate the effects of machine settings on weld quality. The tests were conducted using .040 inch 5Al-5Sn-5Zr and 7Al-12Zr titanium alloys. The test results are not complete enough for reporting at this time. There are, however, three general conclusions which may be drawn. These are (1) 5Al-5Sn-5Zr titanium alloy in general has a higher Tension/Shear Ratio than 7Al-12Zr titanium alloy; (2) using the same machine settings the two alloys are not interchangeable when lap-shear strength is the criterion; and (3) the two alloys do not appear to be susceptible to cracking.

4. **TEST PROGRAM OUTLINE:**

General:

Materials	- 5Al-5Sn-5Zr Titanium Alloy - 7Al-12Zr Titanium Alloy
Gage Thickness (Inches)	-.020 .090 -.040 .125 -.063
Combinations to be Welded	- Two pieces of the same gage and alloy will be welded to make a single joint.
Quality Requirements	- Wherever possible the requirements of Military Specification MIL-W-6858B will be complied with during this investigation.

4.1 **Test Specimen:**

Type - Spot Welds - Lap Shear
Cross-Tension

Tensile - "G" Type per Federal Standard 151

Size - Spot Welds Test Strip:

- Less than .100 inch - 1 X 3 inches
More than .100 inch - 1½ X 4 inches

Tensile - 1 X 6 inch

NOTE: For tests conducted at elevated temperature, specimen length is adjusted to satisfy furnace requirements.

Type Welding Equipment To Be Used - Frequency Converter Type.

4.2 Spot Welding:

4.2.1 Establishment of Machine Settings: For each gage and material noted, machine settings which control current, weld time, and pressure will be varied to determine their effect on weld quality. For each condition to be tested, three lap-shear specimens, two cross-tension specimens, and one three-spot macrospecimen will be made and tested. The macrospecimen will be subjected to radiographic examination.

4.3 Elevated Temperature Test: Elevated temperature tests are to be conducted on the materials noted using a thickness of 0.040 inch. The tests shall consist of the following:

Three lap-shear specimens shall be made and tested at 800 F, 1000 F and 1200 F.

Three lap-shear specimens, two cross-tension specimens and one three-spot macrospecimen shall be welded and subjected to the following temperatures and times:

Temperature (F)	Time(Hours)				
800	50	100	200	400	1000
1000	50	100	200	400	
1200	50	100	200		

NOTE: Two standard tensile test specimens will be subjected to the elevated temperatures with each group of spot welds to determine the effect of the heating cycle on the base material.

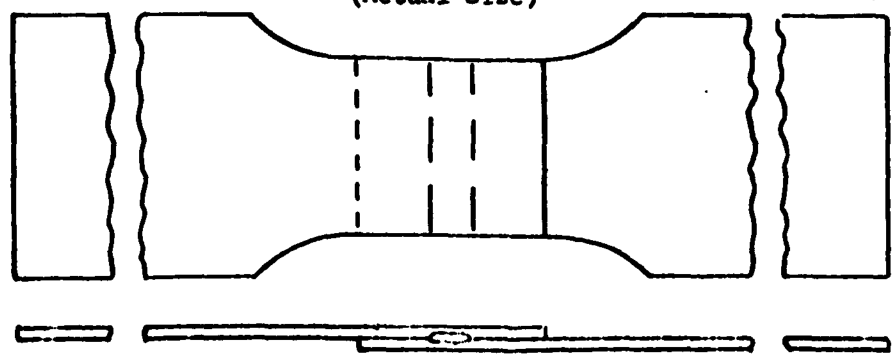
4.4 **Seam Welding:** Seam welding tests will be conducted using .090 inch thickness in both alloys tested. The purpose of the test is primarily to determine joint efficiency. The determination will be made by testing a minimum of three specimens of each type shown in Figure 5. page 82.

5. **FUTURE WORK:** Resistance welding evaluations will be completed and and reported in Progress Report #17.

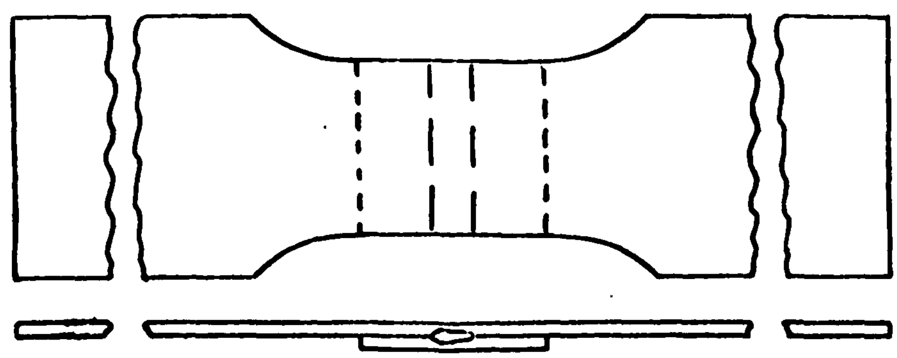
NA57H-527-16
Appendix VII

FIGURE 5

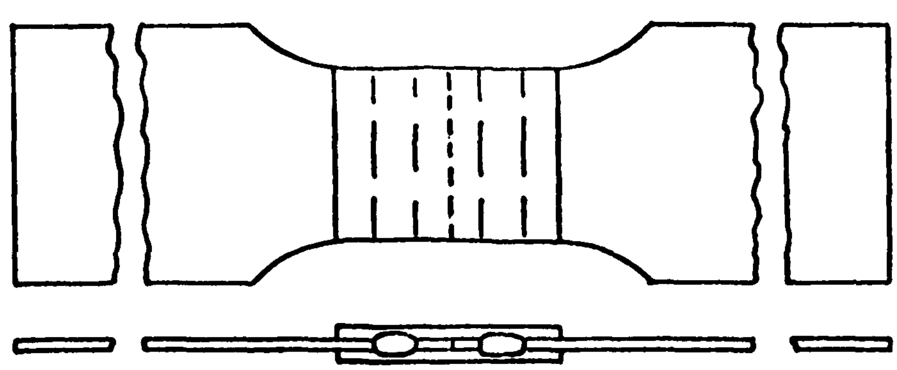
Seam Weld Test Specimen Types
(Actual Size)



Type A



Type B



Type C

FORM N-18-R-1

APPENDIX VIII

DOD HIGH STRENGTH TITANIUM

ALLOY SHEET RESEARCH PROGRAM

Contract NOas 57-785d

Authorized Distribution List

DISTRIBUTION LIST

		No. of Copies
1.	National Academy of Sciences, Materials Advisory Board 2101 Constitution Avenue, Washington 25, D. C. Attn: Dr. W. J. Harris, Jr., Mr. L. L. Gould	2
2.	Convair San Diego, California Attn: Mr. S. R. Carpenter	1
3.	New York University, College of Engineering University Heights, New York 53, New York Attn: Dr. George Gerard	1
4.	Boeing Aircraft Company Seattle, Washington Attn: Mr. T. H. Gray	1
5.	Armour Research Foundation, Technology Center Chicago 16, Illinois Attn: Dr. Donald J. McPherson	1
6.	United Aircraft Corporation Pratt & Whitney Division, East Hartford, Connecticut Attn: Mr. N. Winston Sharp	1
7.	North American Aviation, Incorporated Inglewood, California Attn: Mr. L. P. Spalding	1
8.	Republic Aviation Corporation, Farmingdale Long Island, New York Attn: Mr. Robert Wichser	1
9.	National Bureau of Standards Connecticut Avenue and Van Ness Street, N. W. Washington 25, D. C. Attn: Dr. William Youden	1
10.	CO Watertown Arsenal Watertown 72, Massachusetts Attn: Mr. S. V. Arnold	1
11.	WADC (WCLTL) Attn: Mr. Howard Middendorp	1
12.	Air Material Command (ASC) Wright Patterson Air Force Base, Ohio Attn: Mr. R. Jameson (LMBM)	1

DISTRIBUTION LIST

Continued

		No. of Copies
13.	Titanium Metals Corporation of America Toronto, Ohio Attn: Mr. Harold Kassler	1
14.	Mallory Sharon Titanium Corporation Niles, Ohio Attn: Dr. Dillon Evers	1
15.	Crucible Steel Company of America Midland, Pennsylvania Attn: Dr. Howard Clark	1
16.	Battelle Memorial Institute Columbus, Ohio Attn: Mr. H. R. Ogden & Dr. R. I. Jaffee	2
17.	WADC, Wright Patterson Air Force Base, Ohio Materials Laboratory Attn: Mr. Edward Dugger	1
18.	Grumman Aircraft Engineering Corporation Bethpage, L. I., New York Attn: Mr. Francis X. Drumm	1
19.	University of Syracuse, Research Institute Attn: Dr. George Sachs	1
20.	Chance-Vought Aircraft, Inc. Dallas, Texas Attn: Mr. John W. Seeger	1
21.	Aircraft Industries Association 7660 Beverly Boulevard Los Angeles, California Attn: Mr. H. D. Moran	7
22.	Office of Assistant Secretary of Defense Attn: Research and Engineering	1
23.	Commanding Officer, Diamond Ordnance Fuse Laboratory Washington 25, D. C. Attn: Technical Reference Section - ORDTL-012	1
24.	Naval Air Material Center Aeronautical Materials Laboratory Philadelphia 12, Pennsylvania	1

DISTRIBUTION LIST

Continued

		No. of Copies
25.	Bureau of Ordnance (RE-c) Dept of Navy Washington 25, D. C.	1
26.	Bureau of Ships (Code 343) Dept. of Navy Washington 25, D. C.	1
27.	Office of Naval Research (Code 423) Washington 25, D. C.	1
28.	Naval Research Laboratory Metallurgy Division Washington 25, D. C.	1
29.	National Aviation and Space Agency Washington 25, D. C.	2
30.	Harvey Aluminum Company 19200 Southwestern Avenue Torrence, California	1
31.	Lockheed Aircraft Corporation Structural Research Laboratory Marietta, Georgia Attn: Mr. P. J. Hughes	1
32.	Convair Astronautics Division General Dynamics Corp. San Diego 12, California Attn: A. Hurlich (Mail Zone 595-20)	1
33.	Convair A Division of General Dynamics Corp. Fort Worth, Texas Attn: Mr. W. O. Sunafrank (Dept. 23-2)	1
34.	Republic Steel Corporation Central Alley District Massilon, Ohio Attn: Mr. Tom Perry	1
35.	Titanium Metals Corporation of America New York 7, New York Attn: E. F. Erbin	1
36.	Lockheed Missiles and Space Division 3251 Hanover Street Palo Alto, California Attn: Mr. W. A. Kozumplik, Manager	1

NA57H-527-16

REFERENCES

(Relative to the super alpha titanium sheet alloys evaluations)

Progress Report #14, letter, 61CL4758, dated 24 July 1961. Reporting no progress due to lack of material.

Progress Report #15, letter 61CL7332, dated 20 October 1961. Reporting no progress due to delay in receiving material.

CONTRIBUTORS

N.A.A. Columbus personnel responsible for specific evaluations and/or contributing data under this program are:

Name	Title	Responsibility
M. C. Clapp	Welding Engineer	Fusion Welding
C. C. Lawson	Sr. Development Engr	Machinability
J. E. Lott	Welding Engineer	Resistance Welding
C. A. MacMillan	Research Engineer	Metallurgist
R. R. Richison	Associate Engineer	Dimpling
D. M. Rosenbaum	Research Engineer	Metallurgical Laboratory
R. W. Steur	Specialist Metallurgical	Mechanical Testing
L. P. Streett	Industrial Engineer	Manufacturing Liaison